Electrical Control Kit

Introduction

This kit and student's workbook is provided for your use by Maine Public Service Company to better acquaint you with the types and functions of electrical controls used with materials handling systems and other mechanized operations on the farm.

<u>The controls in the kit are costly and, in many cases, delicate devices and should be handled with care. When doing the exercises, instructions should be followed carefully, all the material should be read and the questions answered. You instructor will check your work and provide the correct answers.</u>

The following are precautions you should be aware of as you do each exercise:

1. The terms "Energize" and "De-energize" are used throughout the exercises and for the purpose of this course mean the following:

"Energize" means to plug in the <u>line cord</u> to supply voltage to the control circuit after the proper connections are made as shown in the wiring schematic.

"De-energize" means to unplug the <u>line cord</u> before proceeding with the next step of the exercise.

2. If you are not sure that you have wired the control correctly, ask the instructor to check it before you energize the circuit.

3. <u>At the completion of each day's work, place the controls back in the storage boxes in a proper manner.</u>

We hope you will enjoy working with this kit and that it will help you to have better understanding of electrical controls and their applications.
Remember - **BE CAREFUL - BE ALERT!**

Introduction

The information is meant to give you an understanding of several common electrical situations that you might encounter. Because of the many options and variations in this area, it is not intended to be a complete guide to electrical work. Never take chances with electrical work. If you feel you need more information, consult your teacher, an electrician, or a more detailed reference book.
You must first learn and demonstrate a basic working knowledge of electricity and electrical terminology. You must demonstrate the ability to read and interpret wiring plans, diagrams, and electrical symbols. You must be able to demonstrate to your instructor that you can complete an electrical circuit. You must also become familiar with basic tools and equipment and how to use them. And, most importantly, you must learn and practice safe work habits.

Safety In the Classroom

1. **Work carefully and remain alert**.

2. **DO NOT TAP INTO LIVE WIRES.** Never work on a "hot" "energized" electrical circuit.

3. In cutting flexible armored cable, BX, or conduit with a hacksaw, be sure to hold the cable against a solid object, not against your knee.

4. Do not cut wire (Romex) with a knife; use proper tools.

5. Remember your eyes are a priceless possession. **Protect your eyes. Wear safety goggles** or a face shield where there is a possibility of being injured by flying chips or electric flashes.

6. **Use tools correctly.** Make sure all tools are in good working condition. Where there is danger of shock, use tools with insulated handles, nonmetallic tools where available. Use dry cloth measuring tape. Use only UL listed power tools. Double insulated power tools offer valuable protection against electric shock. Hand tools such as screwdrivers and pliers should have insulated handles for further protection against shock. **Keep your tools in good condition!**

7. Remove jewelry, rings, watches, and other metal objects or apparel from the body before beginning work. Be sure there are no exposed zippers, or metal buttons.

8. **Handle and lift objects carefully**. When lifting, bend your knees; keep your back as nearly upright as possible.

9. Keep the floor around your working area clean, dry, and free from litter. If necessary, clear the area of loose material or hanging objects.

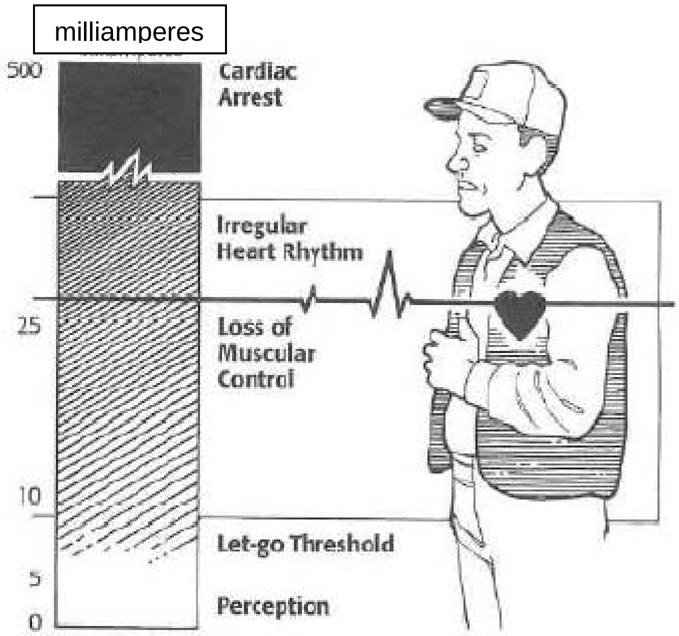
10. When working in a damp area, take precautions against shock. Don't stand on wet ground or a damp floor when using power tools without protecting yourself. Stand on a rubber mat or other non-conducting material for protection. Wear rubber boots or rubber soled shoes.

ALWAYS BE CAREFUL! ALWAYS REMAIN ALERT! THINK BEFORE ACTING! DON'T FOOL AROUND. Many painful accidents occur by the careless and thoughtless antics of the so-called "clown". Your teacher is there to help. Ask for his/her approval before starting work. This will save time and help prevent accidents.   Always Be Safe and Stay Safe.

Metal electrical boxes should be grounded to prevent shocks.

If you are in contact with a live wire or any live component of an energized electrical device—and also in contact with any grounded object—you will receive a shock. Your risk of receiving a shock is greater if you stand in a puddle of water. But you don't even have to be standing in water to be at risk. Wet clothing, high humidity, and perspiration also increase your chances of being electrocuted. Of course, there is always a chance of electrocution, even in dry conditions. Always think safety.

Electrical Safety in the Home



Several factors determine the effect a shock will have on a human body:
1.The duration of contact,
2. The amperage,
3. The path the current takes through the body, and
4. The electrical resistance of the body.

A person standing in water is a better conductor than a person on dry ground.

Taken together, these factors can produce some surprising results. For instance, the current from a 7 1/2 watt Christmas tree bulb (60/ 1000 of an ampere) can kill a person if the current passes through the heart. Figure 1 shows the physiological effects of different current levels.

Shut Off the Power

ALWAYS shut off the breaker (or pull the fuse, in the case of an older house) that feeds the circuit you are about to work on. Most electrical distribution panels have a schedule on them as to which circuit is hooked up to which breaker. **NEVER** trust these, as they may be vague and non-descriptive, or changes may have been made and not documented.

ALWAYS verify that that the circuit is dead before working on it. You can do so by testing to make sure the power is off. Use a voltage tester or a lamp or radio. Plug the meter (lamp or radio) into the receptacle or plug that you want to work on to verify that there is power. One by one, start turning off the breakers until you find the one that shuts off that particular circuit.

You may want to post a sign on the service panel to ensure that nobody attempts to restore power while you are working on the circuits. To really be sure, lock the panel. Always double-check the circuit with a voltage tester before you touch it. Don't restore power until your repair or replacement has been completed.

Be Wary of Service Panels

The two or three large wires entering a panel from the outside REMAIN LIVE, even if you have shut off the switch or breakers. **NEVER** touch service wires, and don't work near them with a metal ladder. If you think there is a problem with these wires, play it safe and contact the power company.

Don't Stand On a Wet Floor

To avoid potentially dangerous shocks, **NEVER** stand in water or on a wet floor. Put down dry boards or a rubber mat to stand on while you work. And **NEVER** work with electricity when you are wet - be safe and change into dry clothes.

Do Not Touch Metal

Metal conducts electricity; if you happen to touch metal while also touching a live wire, current can then flow through your body, increasing the chance of dangerous shocks.

The Right Tools for the Job

Tools with rubber or plastic coated handles are insulated. Wear shoes with non-conductive soles, such as rubber-soled shoes or sneakers. Also consider wearing safety goggles or glasses, and gloves if practical.

Test It Out

When you have completed your electrical project, turn the power back on and check your work with a voltage tester (lamp or radio).

Circuit Protection

When a fuse blows or a circuit breaker is tripped, remember:

- The circuit breaker or the fuse should never be bypassed because this can damage equipment or start a fire if the circuit becomes overheated.
- Never replace a fuse with one that is larger than that specified for the circuit. A fuse that is too large will not protect against an overload, which can cause a fire.
- Do not replace fuses with pennies, nails, bar stock, or other objects. Many electrical fires have been caused by such substitutions.

When in Doubt ....

NEVER push yourself when working on any electrical project. Make sure you give yourself the time to think the project through thoroughly; mistakes happen when we rush projects. Use good judgment - if you still don't feel comfortable, leave the job to a qualified electrician.

Safety Work Rules Review

Safety is of utmost importance when working with electricity. Develop safe work habits and stick to them. Be very careful with electricity. It may be invisible, but it can be dangerous if not understood and respected.

1. Safety glasses or goggles should be worn whenever power tools are used, especially if you wear contact lenses.
2. Make sure the power is off at the breaker box before doing any electrical work
3. Always work in a clean, dry area free from anything wet.
4. Wires should only be connected at accessible junction boxes. Never splice wires together and conceal them within a wall without a junction box.
5. Never attempt to strip wires with a knife. Aside from endangering your fingers, you will nick the wire metal, which will create an electrical hazard.
6. Ground fault circuit interrupter outlets should be used under damp conditions (basements, bathrooms, outdoors, etc.), as required by the National Electric Code.
7. Don't create fire hazards by overloading an outlet or an extension cord.
8. Avoid electrical shock by mapping and marking your switch and outlet boxes. Put the map on the door of the main power service panel.
9. Leave a warning message that you are working on the circuit at the service panel, and tape the circuit breaker in the off position. With a fuse box, take the fuse out.
10. Never change the size of a fuse or breaker in a circuit.
11. Be certain your connector is CO/ALR rated when you splice aluminum wire. If it is marked CU/ALR, use only copper wire. Do not use aluminum wire with push terminals; use only copper or copper clad aluminum wire.
12. Always correct the problem that caused a fuse or circuit breaker to blow before replacing the fuse or circuit breaker.
13. Replace wiring that shows signs of fraying or deterioration.
14. Avoid breaking your knuckles by bracing the powerful right-angle drill so that it cannot spin around if it gets stuck while drilling.
15. Before working with wires or electrical connections, check them with a voltage tester to be sure they are dead.
16. Plumbing and gas pipes are often used to ground electrical systems. Never touch them while working with electricity.
17. Don't use metal ladders with overhead electricity.
18. Use the proper protection, take precautions, and plan ahead. Never by-pass safety to save money or to rush a project. **ALWAYS BE SAFE!**

Recipe for Electrical Safety

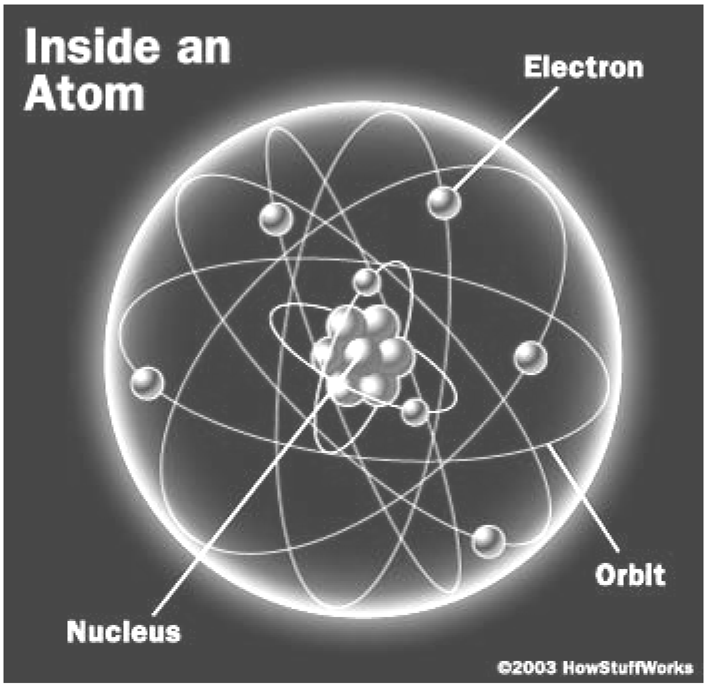
1 well-wired building
Knowledge of safe electrical practices
1 main cut off switch in your building
1 plug per electrical outlet opening
1 on/off switch per appliance
2 dry hands
1 pair of dry cotton or plastic gloves
1 ampere tester
1 hardhat for each electrician
Adequate time for the job
Wire sized according the designated use(s)
Very dry floors and work surfaces
Enough lightening rods to protect the building
A knowledge of how to use electrical equipment
1 electrician, well-trained and up-to-date
1 thorough electrical inspector
1 electrical code book
Careful attitudes of many consumers
Several safety seeds
Concern for tomorrow's needs

Directions: Combine all ingredients except last 2. Mix evenly and generously and absorb in your mind. Each time electrical equipment is used, bring this mixture along. Prepare generous recipe ahead of time for use during damp or wet or unsafe conditions. When you use this mixture, sprinkle the seeds evenly. If you cannot locate tomorrow and safety seeds, add more of ingredients number 2. Plant seeds around the home, school, workplace, and community.

Use this recipe consistently, preferably daily. When children, aged, and untrained users of equipment and electrical hazard occur, mix up a batch from this recipe and serve as soon as possible. Failure to use this recipe can be a critical problem. Lack of use of this recipe too often leads to injury and loss of property and life.

Electron Theory

Electron theory helps to explain electricity. The basic building block for matter, **anything that has mass and occupies space, is an atom**. All matter, solid, liquid, or gas – is made up of molecules, or atoms joined together. These atoms are the smallest particles into which an element or substance can be divided without losing its properties. There are only about 100 different atoms that make up everything in our world. The features that make one atom different from another also determine its electrical properties.



Atomic Structure

An atom is like a tiny solar system. **The center is called the nucleus, made up of tiny particles called protons and neutrons. The nucleus is surrounded by clouds of other tiny particles called electrons.** The electrons rotate about the nucleus in fixed paths called shells or rings. Hydrogen has the simplest atom with one proton in the nucleus and one electron rotating around it. Copper is more complex with 29 electrons in four different rings rotating around a nucleus that has 29 protons and 29 neutrons. Other elements have different atomic structures.

Atoms and electrical charges

Each atomic particle has an electrical charge.
Electrons have a negative (-) charge.
Protons have a positive charge (+).
Neutrons have no charge; **they are neutral.**

In a balanced atom, the number of electrons equals the number of protons. The balance of the opposing negative and positive charges holds the atom together. Like charges repel, unlike charges attract. The positive protons hold the electrons in orbit. Centrifugal force prevents the electrons from moving inward. And, the neutrons cancel the repelling force between protons to hold the atom's core together.

Positive and negative ions

If an atom gains electrons, it becomes a negative ion. If an atom loses electrons, it becomes a positive ion. Positive ions attract electrons from neighboring atoms to become balanced. This causes electron flow.

Electron Flow

The number of electrons in the outer orbit determines the atom's ability to conduct electricity. Electrons in the inner rings are closer to the core, strongly attracted to the protons, and are called bound electrons. Electrons in the outer ring are further away from the core, less strongly attracted to the protons, and are called free electrons.

Electrons can be freed by forces such as friction, heat, light, pressure, chemical action, or magnetic action. These freed electrons move away from the electromotive force, or EMF ("electron moving "force"), from one atom to the next. **A stream of free electrons forms an electrical current.**

Conductors and Insulators

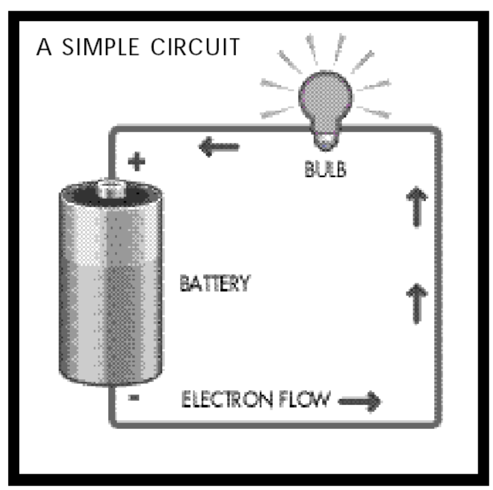
The electrical properties of various materials are determined by the number of electrons in the outer ring of their atoms.

Conductors – Materials with 1 to 3 electrons in the atom's outer ring make good conductors. **Gold, silver, copper, aluminum, iron, etc., all have free electrons.** The loose electrons make it easy for electricity to flow through these materials, so they are known as **electrical conductors**. They conduct electricity. The moving electrons transmit electrical energy from one point to another. The electrons are held loosely, there's room for more, and a low EMF will cause a flow of free electrons.

Insulators – Materials with 5 to 8 electrons in the atom's outer ring are insulators. The electrons are held tightly, the ring's fairly full, and a very high EMF is needed to cause any electron flow at all. **Such materials include glass, rubber, and certain plastics.** These are all examples of materials in which electrons stick with their atoms. Because the electrons don't move, these materials cannot conduct electricity very well, if at all.

Current Flow

The electron theory states that current flows from (-) to (+)… excess electrons cause an area of negative potential (-) and flow toward an area lacking electrons, an area of positive potential (+), to balance the charges.



<u>Voltage</u> (named after Alessandro Volta -1745–1827).

- **Voltage is electrical pressure, a potential force or difference in electrical charge between two points.**
- It can push electrical current through a wire, but not through its insulation**.**
- **Voltage is measured in volts**. One volt can push a certain amount of current, two volts twice as much, and so on.
- **A voltmeter measures the difference in electrical pressure between two points in volts.**
    - **A voltmeter is used in parallel.**
- Voltage is usually designated by the letter "E" in the Ohms formula.
- It refers to the pressure which is required to force the electrons through the circuit.
- This is the pressure that makes them move when an appliance starts or a light is turned on.
- This pressure is available in your wiring circuits all the time, whether you are using your electrical equipment or not.
- **Voltage is called "electromotive force." Whenever two points of unequal potential or voltage are connected, current flows.**
- **The greater the EMF or voltage, the greater the amount of current flow.**
- Voltage will differ on certain types of equipment, but it is usually 120 volts here in North America.
- Some equipment that operates on one volt will show a high and low voltage on the nameplate, such as 100-120.
    - This means that any voltage between these two figures should be satisfactory for operating that piece of equipment.
    - Using a higher voltage will result in a greater current flow and burn out the lamp, while a lower voltage will not cause enough current flow to make the lamp light up normally.

<u>Current</u> *(named after* ***Andre Ampere*** **1775-1836***)*

- **Current is electrical flow (MOVEMENT OF ELECTRONS) moving through a wire.**
- Current flows in a wire pushed by voltage.
- **Current is measured in amperes, or amps, for short**.
- **An ammeter measures current flow in amps. It is inserted into the path or current flow, or in series, in a circuit.**
- Electrons in motion are current flow and the ampere is the unit of measurement for this current flow.
- **The symbol "I" is used in calculations and schematic drawings to designate current flow.**
    - **I = Current Flow (Ampere).**
    - **To determine if the load is too heavy for the circuit, divide watts by volts to get amperes.**
    - **Thus, 1200 watts/120 volts = 10 amperes.** Ten amperes is under the 15 ampere fuse.

<u>Watts</u> (named after James Watt (1736-1819). He created the term "horsepower" and invented the steam engine.)

- Electricity is measured in units of power called watts.
- One watt is a very small amount of power. It would require nearly 750 watts to equal one horsepower.
- A kilowatt represents 1,000 watts.
- A kilowatthour (kWh) is equal to the energy of 1,000 watts working for one hour.
- The amount of electricity a power plant generates or a customer uses over a period of time is measured in kilowatt hours (kWh).
- Kilowatt hours are determined by multiplying the number of kW's required by the number of hours of use. You buy electrical energy by kilowatt hours.
    - For example, if you use a 40-watt light bulb 5 hours a day, you have used 200 watts of power, or 0.2 kilowatthours of electrical energy. Or, 100-watt light bulb for 10 hours — that is, 1 kilowatt hour.
    - To get kilowatt hours of electrical energy, you divide the number of watt-hours by 1,000. So, 1,000/1,000 = 1 kWh.
- Watts can be measured with an instrument called a **watt meter**.

Resistance (named after Georg Simon Ohm (1787-1854)

- **Resistance opposes current flow. It is like electrical "friction." This resistance slows the flow of current.**
- Every electrical component or circuit has resistance.
- This resistance charges electrical energy into another form of energy – heat, light, motion.
- **Resistance, is measured in ohms.**
- **A special meter, called an ohmmeter, can measure the resistance of a device in ohms when no current is flowing.**

Factors Affecting Resistance

Five factors determine the resistance of conductors: length of the conductor, diameter, temperature, physical condition, and conductor material.

Length

Electrons in motion are constantly colliding as voltage pushes them through a conductor. **If two wires are the same material and diameter, the longer wire will have more resistance than the shorter wire.** Wire resistance is often listed in ohms per foot (e.g., spark plug cables at 5 Ω per foot.) Length must be considered when replacing wires.

Diameter

Large conductors allow more current flow with less voltage. If two wires are the same material and length, the thinner wire will have more resistance than the thicker wire. Wire resistance tables list ohms per foot for wires of various thicknesses (e.g. size or gauge…1, 2, 3 are thicker with less resistance and more current capacity; 18, 20, 22 are thinner with more resistance and less current capacity). Replacement wires and splices must be the proper size for the circuit current.

Temperature

In most conductors, resistance increases as the wire temperature increases. Electrons move faster, but not necessarily in the right direction. **Most insulators have less resistance at higher temperatures.**

Physical Condition

Partially cut or nicked wire will act like small wire with high resistance in the damaged area. A kink in the wire, poor splices, and loose or corroded connections also increase resistance. Take care not to damage wires during testing or stripping insulation.

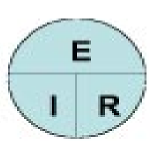
Material

Materials with many free electrons are good conductors with low resistance to current flow. Good conductors are copper, aluminum, and gold. Materials **with many bound electrons are poor conductors (insulators) with high resistance to current flow**. They are: rubber, glass, paper, ceramics, plastics, and air – all have high resistance.

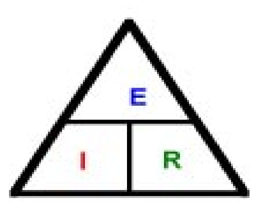
OHM'S LAW

Georg Simon Ohm (1787-1854) was the person who discovered how amps, resistance, power and watts are tied together mathematically.

Ohm's Law says: The current in a circuit is directly proportional to the applied voltage and inversely proportional to the amount of resistance. This means that if the voltage goes up, the current flow will go up, and vice versa. Also, as the resistance goes up, the current goes down, and vice versa.



OR



Based on this Law, any given Voltage, Resistance, or Current can be found by knowing any 2 of the 3 factors. These factors are known as:

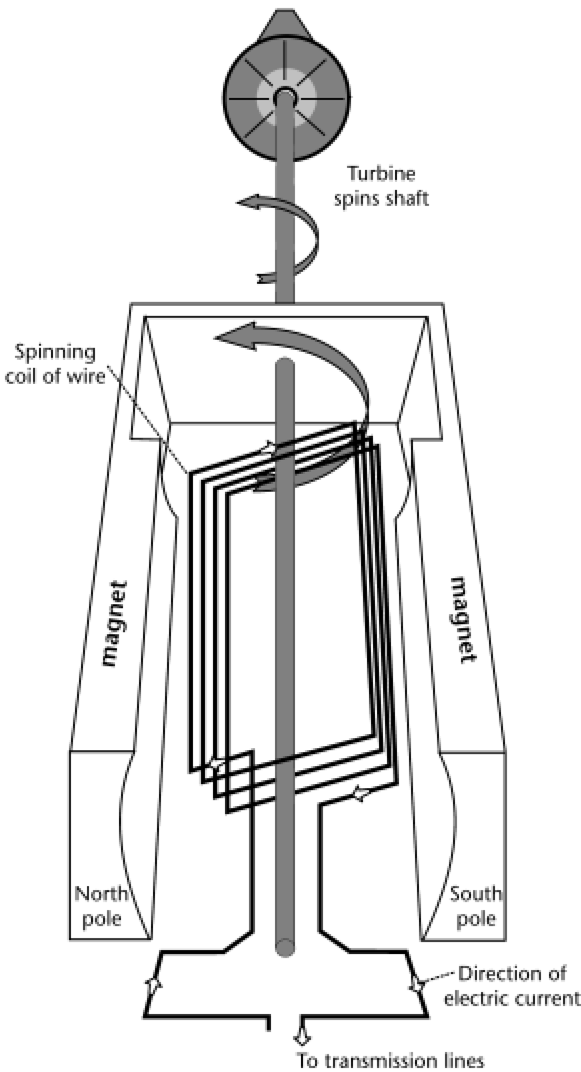
E = Volts   I = Current   R = Resistance

Current is affected by either voltage or resistance. If the voltage is high or the resistance is low, current will be high. If the voltage is low or the resistance is high, current will be low.

Resistance is not affected by either voltage or current. It is either too low, okay, or too high. If resistance is too low, current will be high at any voltage. If resistance is too high, current will be low if voltage is okay.

HOW ELECTRICITY IS GENERATED

TURBINE GENERATOR



An electric generator is a device for converting mechanical energy into electrical energy. The process is based on the relationship between magnetism and electricity. When a wire or any other electrically conductive material moves across a magnetic field, an electric current occurs in the wire. The large generators used by the electric utility industry have a stationary conductor. A magnet attached to the end of a rotating shaft is positioned inside a stationary conducting ring that is wrapped with a long, continuous piece of wire. When the magnet rotates, it induces a small electric current in each section of wire as it passes. Each section of wire constitutes a small, separate electric conductor. All the small currents of individual sections add up to one current of considerable size. This current is what is used for electric power.

The purpose of a generator is to convert motion into electricity. The GENERATOR is a simple device that moves a magnet near a wire to create a steady flow of electrons. It uses a magnet to get electrons moving. If you move a magnet near a wire, the magnetic field will cause electrons in the wire to move. Because the electrons flow first in one direction and in the other, the generator produces alternating current.

An electric utility power station uses either a turbine, engine, water wheel, or other similar machine to drive an electric generator or a device that converts mechanical or chemical energy to generate electricity. Steam turbines, internal-combustion engines, gas combustion turbines, water turbines, and wind turbines are the most common methods to generate electricity. Most power plants are about 35 percent efficient. That means that for every 100 units of energy that go into a plant, only 35 units are converted to usable electrical energy.

Most of the electricity in the United States is produced in steam turbines. A turbine converts the kinetic energy of a moving fluid (liquid or gas) to mechanical energy. Steam turbines have a series of blades mounted on a shaft against which steam is forced, thus rotating the shaft connected to the generator. In a fossil-fueled steam turbine, the fuel is burned in a furnace to heat water in a boiler to produce steam.

Coal, petroleum (oil), and natural gas are burned in large furnaces to heat water to make steam that in turn pushes on the blades of a turbine. Did you know that coal is the largest single primary source of energy used to generate electricity in the United States? In 2005, half (50%) of the country's 3.9 trillion kilowatthours of electricity used coal as its source of energy.

Natural gas, in addition to being burned to heat water for steam, can also be burned to produce hot combustion gases that pass directly through a turbine, spinning the blades of the turbine to generate electricity. Gas turbines are commonly used when electricity utility usage is in high demand. In 2005, 19% of the nation's electricity was fueled by natural gas.

Petroleum can also be used to make steam to turn a turbine. Residual fuel oil, a product refined from crude oil, is often the petroleum product used in electric plants that use petroleum to make steam. Petroleum was used to generate about three percent (3%) of all electricity generated in U.S. electricity plants in 2005.

Nuclear power is a method in which steam is produced by heating water through a process called nuclear fission. In a nuclear power plant, a reactor contains a core of nuclear fuel, primarily enriched uranium. When atoms of uranium fuel are hit by neutrons they fission (split), releasing heat and more neutrons. Under controlled conditions, these other neutrons can strike more uranium atoms, splitting more atoms, and so on. Thereby, continuous fission can take place, forming a chain reaction releasing heat. The heat is used to turn water into steam that, in turn, spins a turbine that generates electricity. Nuclear power was used to generate 19% of all the country's electricity in 2005.

Hydropower, the source for almost 7% of U.S. electricity generation in 2005, is a process in which flowing water is used to spin a turbine connected to a generator. There are two basic types of hydroelectric systems that produce electricity. In the first system, flowing water accumulates in reservoirs created by the use of dams. The water falls through a pipe called a penstock and applies pressure against the turbine blades to drive the generator to produce electricity. In the second system, called run-of-river, the force of the river current (rather than falling water) applies pressure to the turbine blades to produce electricity.

Geothermal power comes from heat energy buried beneath the surface of the earth. In some areas of the country, enough heat rises close to the surface of the earth to heat underground water into steam, which can be tapped for use at steam-turbine plants. This energy source generated less than 1% of the electricity in the country in 2005.

Solar power is derived from the energy of the sun. However, the sun's energy is not available full-time and it is widely scattered. The processes used to produce electricity using the sun's energy have historically been more expensive than using conventional fossil fuels. Photovoltaic conversion generates electric power directly from the light of the sun in a photovoltaic (solar) cell. Solar-thermal electric generators use the radiant energy from the sun to produce steam to drive turbines. In 2005, less than 1% of the nation's electricity was based on solar power.

Wind power is derived from the conversion of the energy contained in wind into electricity. Wind power, less than 1% of the nation's electricity in 2005, is a rapidly growing source of electricity. A wind turbine is similar to a typical wind mill.

Biomass includes wood, municipal solid waste (garbage), and agricultural waste, such as corn cobs and wheat straw. These are some other energy sources for producing electricity. These sources replace fossil fuels in the boiler. The combustion of wood and waste creates steam that is typically used in conventional steam-electric plants. Biomass accounts for about 2% of the electricity generated in the United States.

THE TRANSFORMER - MOVING ELECTRICITY

To solve the problem of sending electricity over long distances, George Westinghouse developed a device called a transformer. The transformer allowed electricity to be efficiently transmitted over long distances. This made it possible to supply electricity to homes and businesses located far from the electric generating plant.

The electricity produced by a generator travels along cables to a transformer, which changes electricity from low voltage to high voltage. Electricity can be moved long distances more efficiently using high voltage. Transmission lines are used to carry the electricity to a substation. Substations have transformers that change the high voltage electricity into lower voltage electricity. From the substation, distribution lines carry the electricity to homes, offices and factories, which require low voltage electricity.

Transporting Electricity

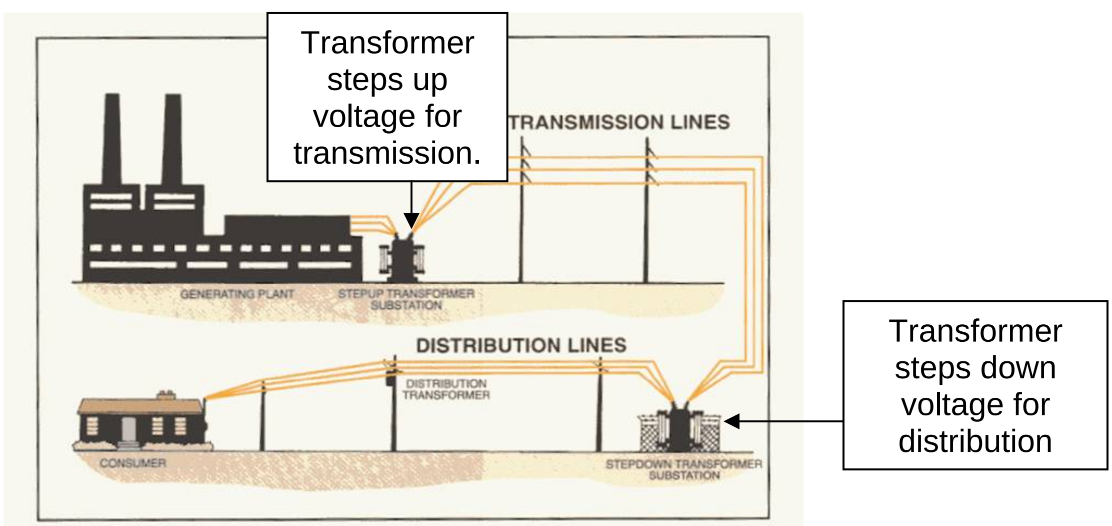


Figure 4-1. Electric energy is generated, transformed, transmitted, and distributed to the consumer.

Watts and Kilowatt-hours

As their names imply, a watt hour, abbreviated Wh, is the equivalent of 1 W dissipated for an hour, and 1 kilowatt hour (kWh) is the equivalent on 1 kW of power dissipated for 1 hour.

If you live in the United States, the power outlets in the wall of your house or apartment are delivering 120 volts.

Imagine that you plug a space heater into a wall outlet. You measure the amount of current flowing from the wall outlet to the heater, and it is 10 amps (Amps= Watts/volts). That means that it is a 1,200-watt heater.

Volts X Amps = Watts

... so 120 volts X 10 amps = 1,200 watts.

This is the same for any electrical appliance. If you plug in a toaster and it draws 5 amps, it is a 600-watt toaster. If you plug in a light and it draws half an amp, it is a 60-watt light bulb. (120 volts X .5 amps = 60 Watts)

Let's say that you turn on the space heater, you go outside and you look at the **power meter**. The purpose of the power meter is to measure the amount of electricity flowing into your house so that the power company can bill you for it. Let's assume that nothing else in the house is on, so the meter is measuring only the electricity used by the space heater.

Your space heater is using 1,200 watts. That is 1.2 kilowatts -- a kilowatt is 1,000 watts (1,200 watts/1,000). If you leave the space heater on for one hour, you will use 1.2 **kilowatt-hours** of power. If your power company charges you 13 cents per kilowatt-hour, then the power company will charge you 16 cents for every hour that you leave your space heater on.

1.2 kilowatts X 1 hour = 1.2 kilowatt-hours

1.2 kilowatt-hours X 17 cents per kilowatt-hour = 20 cents

Similarly, if you have a 100-watt light and you leave it on for 10 hours, the light will consume 1 kilowatt-hour (100 watts X 10 hours = 1 kilowatt-hour – 17 cents for that one kilowatt-hour).

If you have a 20,000-watt heat pump and you leave it on for five hours every day, you will consume 100 kilowatt-hours per day (20 kilowatts X 5 hours = 100 kilowatt-hours), or 17 dollars of power per day if a kilowatt-hour costs seventeen cents. If you do that for a month, your heat pump costs you (30 X $17) $510 per month. That is why your electric bills can get so high when the temperature is very cold -- the heat pump runs a lot.

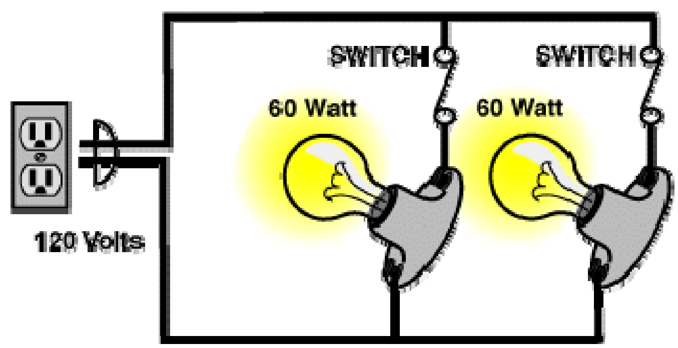
Circuits

An Electrical circuit is an unbroken path along which an electric current exists or is intended or able to flow. A simple circuit might consist of an electric cell (the power source), two conducting wires (one end of each being attached to each terminal of the cell), and a small lamp (the load) to which the free ends of the wires leading from the cell are attached. When the connections are made properly, current flows, the circuit is said to be "closed," and the lamp will light. The current flows from the cell along one wire to the lamp, through the lamp, and along the other wire back to the cell. When the wires are disconnected, the circuit is said to be "open" or "broken." In practice, circuits are opened by such devices as switches, fuses, and circuit breakers

Electrical circuits can get quite complex. But at the simplest level, you always have the source of electricity (a battery, etc.), a load (a light bulb, motor, etc.), and two wires to carry electricity between the battery and the load. Electrons move from the source, through the load and back to the source.

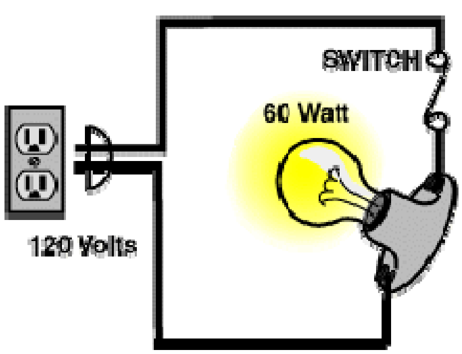
Moving electrons have **energy**. As the electrons move from one point to another, they can do **work**. In an incandescent light bulb, for example, the energy of the electrons is used to create heat, and the heat in turn creates light. In an electric motor, the energy in the electrons creates a magnetic field, and this field can interact with other magnets (through magnetic attraction and repulsion) to create motion. Each electrical appliance harnesses the energy of electrons in some way to create a useful side effect.

Parallel Circuits



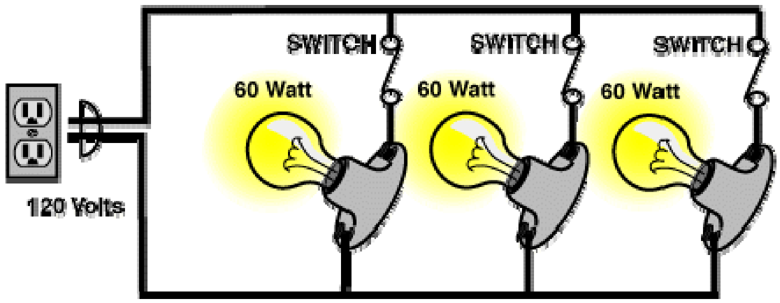
A parallel circuit is a circuit in which there are at least two independent paths in the circuit to get back to the source. In a parallel circuit, the current will flow through the closed paths and not through the open paths.

Consider a simple circuit with an outlet, a switch and a 60 watt light bulb. If the switch is closed, the light operates. When a second 60 watt bulb is added to the circuit in parallel with the first bulb, it is connected so that there is a path to flow through to the first bulb or a path to flow through to the second bulb. Note that both bulbs glow at their intended brightness, since they each receive the full circuit voltage of 120 volts.



Every load connected in a separate path receives the full circuit voltage. If a third 60-watt bulb is added to the circuit, it also glows at its intended brightness since it also receives its full 120 volts from the source.

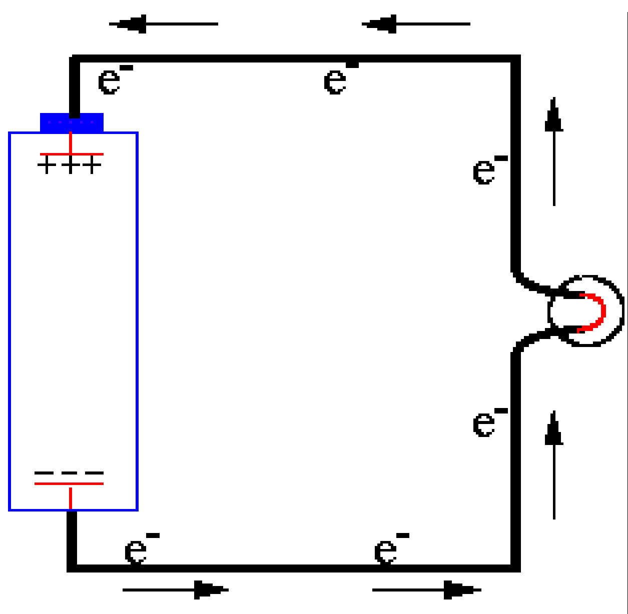
One special concern in parallel circuits is that the amperage from the source increases each time another load is added to the circuit in parallel. Therefore, it is very easy to keep adding loads or plugging them in parallel and thereby overloading a circuit by requiring more current to flow than the circuit can safely handle.



An obvious advantage of parallel circuits is that the burnout or removal of one bulb does not affect the other bulbs in parallel circuits. They continue to operate because there is still a separate, independent closed path from the source to each of the other loads. That's why parallel circuits are used for wiring lighting and receptacle outlets. If one light on a parallel circuit burns out, it is the only one that quits and the other lights wired in parallel stay on.

Direct Current vs. Alternating Current

Batteries, fuel cells and solar cells all produce something called direct current (DC). The positive and negative terminals of a battery are always, respectively, positive and negative. **Current always flows in the same direction between those two terminals –from the negative to the positive.**



The power that comes from a power plant, on the other hand, is called alternating current (AC). The direction of the current reverses, or alternates, 60 times per second (in the U.S – 60 hertz.) or 50 times per second (in Europe, for example). The power that is available at a wall socket in the United States is **120-volt, 60-cycle AC power**. The big advantage that alternating current provides for the power grid is the fact that it is relatively easy to change the voltage of the power, using a device called a **transformer**. A transformer is an electrical device that takes electricity of one voltage and changes it into another voltage. You'll see transformers at the top of utility poles and even changing the voltage in a toy train set.

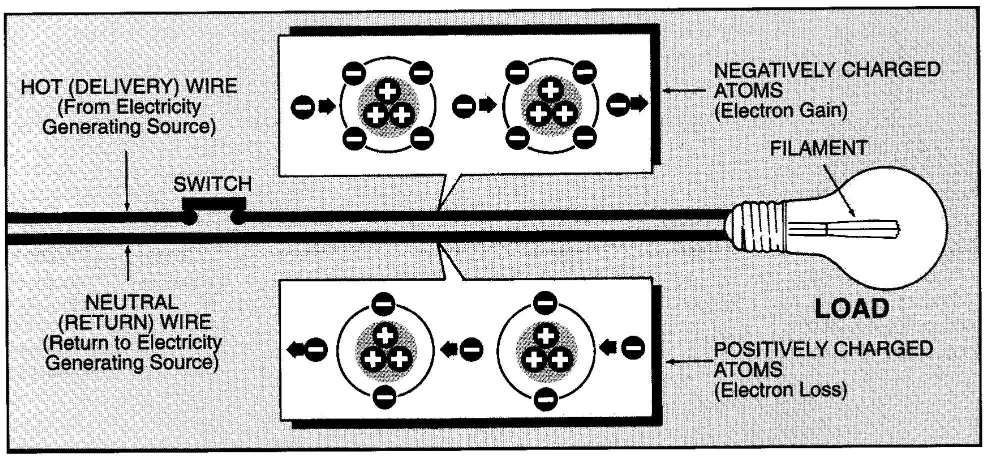


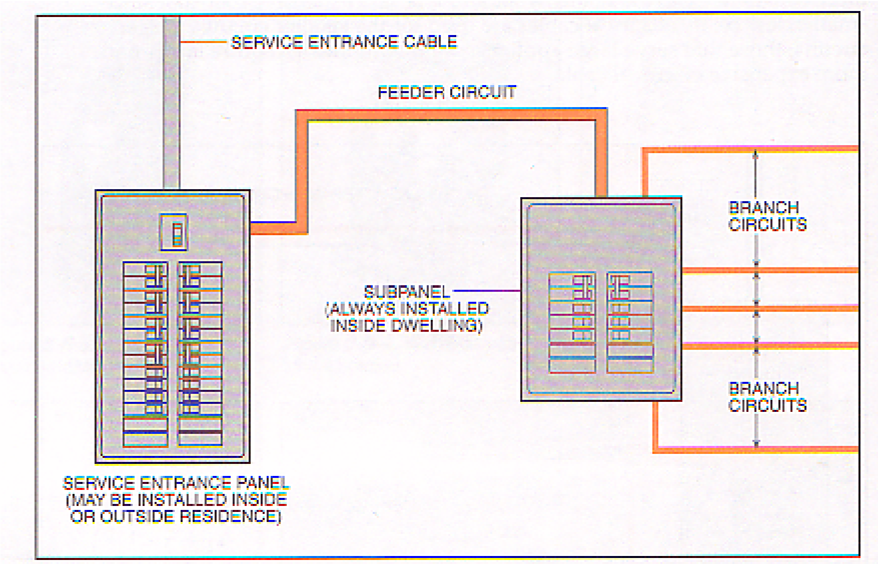
Figure 1-B-1. A simple electric circuit.

Types of Electrical Circuit

Electricity travels in a circle. It moves along a "hot" wire toward a light or receptacle, supplies energy to the light or appliance, and then returns along the neutral wire to the source. This complete path is a circuit. In house wiring, a circuit usually indicates a group of lights or receptacles connected along such a path.

There are two basic types of electrical circuits used in a residential wiring system: Branch Circuits and Feeder Circuits

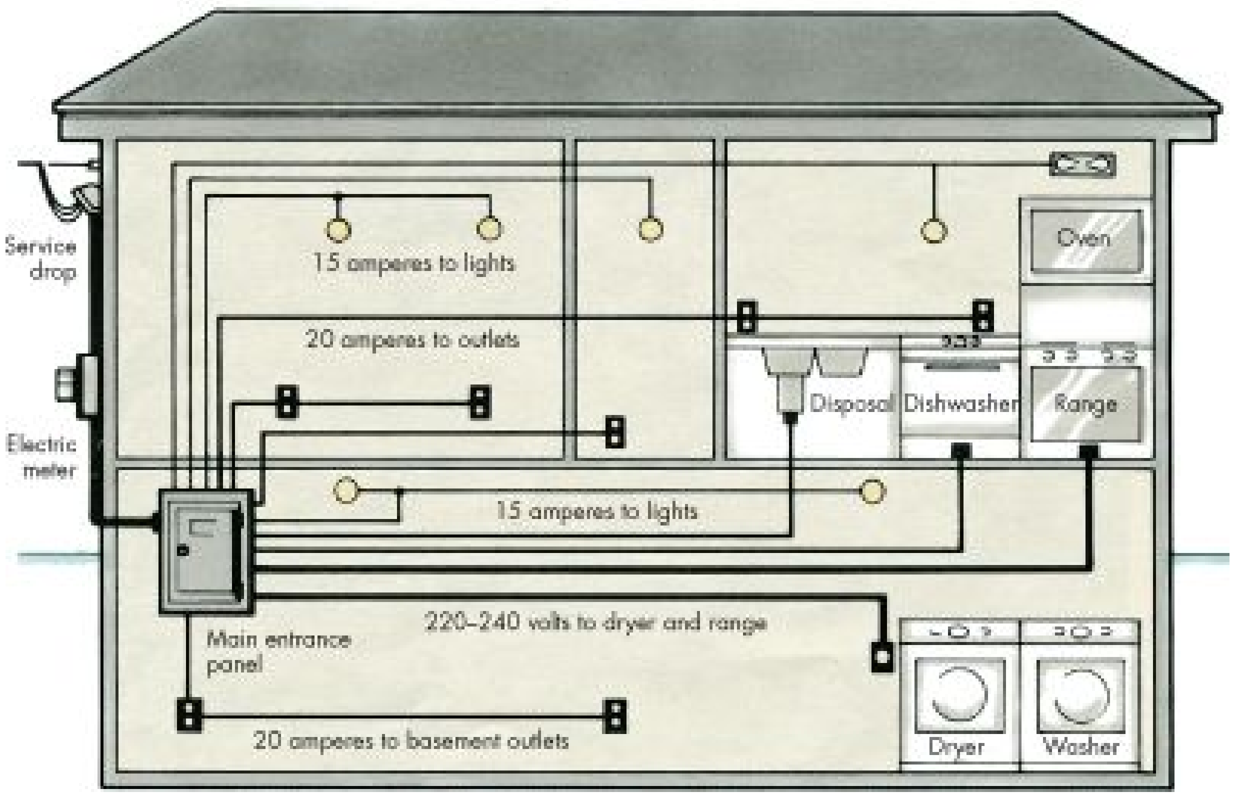
Branch circuits are defined as the conductors between the circuit breaker and the last outlet, switch or receptacle on the circuit. Most circuits installed in residences are of the branch circuit type. They run from the circuit breaker in the Service Entrance Panel (SEP), or the subpanel, to the one or more outlets, such as lights or receptacles. Each branch circuit is protected by its own circuit breaker. Having several branch circuits in a home wiring system make the home wiring system more efficient and less expensive to install.



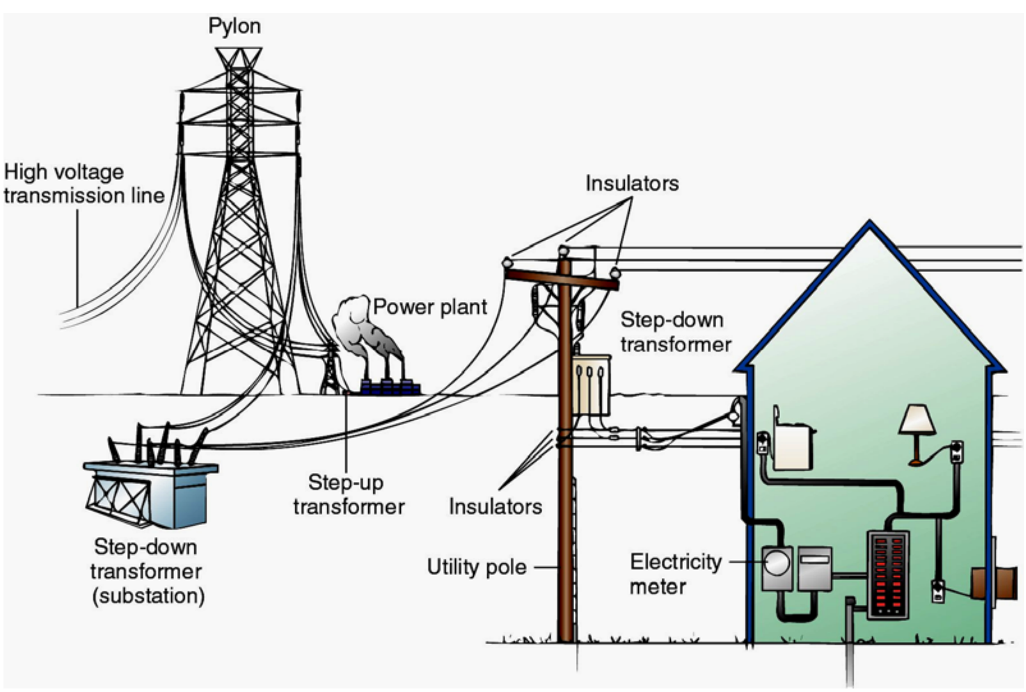
Feeder Circuits are defined as those circuits that run between the SEP and a subpanel. A feeder circuit may also originate at a generator or battery. In order for electricity to flow and do useful work for us, it must have a complete path or circuit form its source to the point of use and back again. The 110-120-volt branch circuits go through fuses or breakers, which are labeled either 15 or 20 amps. The 15-amp branches go to ceiling lamps and wall receptacles in rooms where less energy-demanding devices, such as table lamps, are found. The larger 20-amp circuits go to receptacles in the kitchen, dining, and laundry areas where heavy-duty appliances are used.

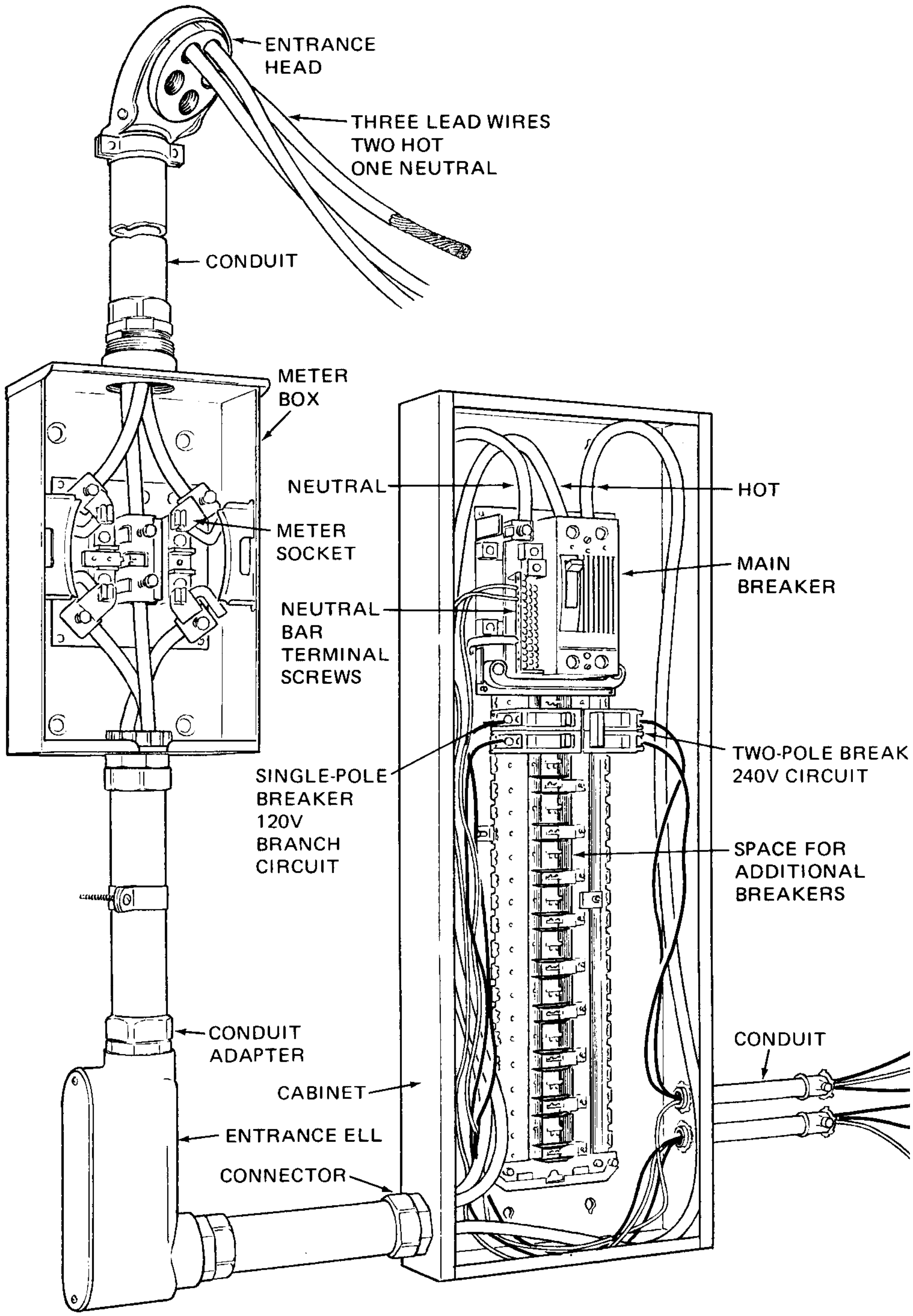
A 15-amp circuit can handle a total of 1,800 watts, while a 20-amp circuit can handle a total of 2,400 watts, but these figures represent circuits that are fully loaded. In practice, you should limit the load on a 15-amp circuit to no more than 1,440 watts, and the load on a 20-amp line should exceed no more than 1,920 watts.

How can you know the load on a circuit? Add up the individual wattages for all lamps and appliances plugged into each circuit. When computing the load on each branch circuit, allow for motor-driven appliances that draw more current when the motor is just starting up than when it's running. A refrigerator, for example, might draw up to 15 amps initially but will quickly settle down to around 4 amps. Suppose the refrigerator is plugged into a 20-amp branch circuit and a 1,000-watt electric toaster (which draws a little more than 8 amps) is also plugged into that circuit. If the refrigerator motor starts while the toaster is toasting, the total current load will exceed the current-carrying capacity of the circuit, and the fuse will blow or the circuit breaker will trip.**There are two types of circuits, series and parallel. In a series circuit, the electricity only has one path as it flows through the circuit. It must travel through each one to get to the next. If a bulb burns out or is removed, all the lights in the series circuit go out. Parallel circuits involve more than one path and are like many circuits combined. When lights are wired in parallel, the current splits and goes through each bulb separately. When a bulb is removed in a parallel circuit, the other bulbs in the circuit are not affected. Each separate wire in your home is a parallel circuit.** For example, all outlets and lights in your bedroom and perhaps another room may be connected in parallel to one electrical circuit. All the lights and outlets in the living room may make up another parallel circuit. Large appliances, such as an electric hot water heater, may have heir own circuit. In general, a house will have several parallel circuits for lights and outlets and several for large appliances. Each branch circuit is connected in parallel to the main power supply entering the house. These main lines are called "service drop because the lines are usually dropped from a utility pole to service your home. Today many subdivisions use underground wiring so the "service drop" doesn't really drop at all!



Newer homes have three incoming power lines that supply 110-120/220-240 volts AC. This provides 110-120 volts for lighting, outlets, and small appliances and 220-240 volts for heavier appliances.





ENTRANCE HEAD
THREE LEAD WIRES TWO HOT ONE NEUTRAL
CONDUIT
METER BOX
NEUTRAL
HOT
METER SOCKET
MAIN BREAKER
NEUTRAL BAR TERMINAL SCREWS
TWO-POLE BREAK 240V CIRCUIT
SINGLE-POLE BREAKER 120V BRANCH CIRCUIT
SPACE FOR ADDITIONAL BREAKERS
CONDUIT ADAPTER
CONDUIT
CABINET
ENTRANCE ELL
CONNECTOR

Grounding

Basic Rules of Electricity

When working around electricity, there are some critical fundamentals that you need to be aware of. Electricity **ALWAYS** seeks the quickest path back to its source or to the earth. The process of grounding adds protection against electrical shock by ensuring that YOU or any other individual does not become a path through which electricity moves.

Why Ground?

Proper grounding provides a safe path for electricity to safely move from a defective outlet, fixture, appliance or tool back into the earth, which happens to be a very good electrical conductor. Homes are grounded by either the use of ground electrodes (ground rods) or by ground plates. Another grounding option sometimes used is the home's cold water supply pipe, providing that it is copper and is continuous to the water main. (Check local authority and code rules.)

Polarized Receptacles

If you live in an older home (pre 1960's), you may have "polarized", rather than grounded receptacles. Polarized receptacles operate on a 2-wire vs. a 3-wire system. A polarized receptacle visibly differs from a grounded receptacle as they are two, rather than three-pronged. Important to note that you cannot change a polarized receptacle to a 3-prong grounded receptacle without either grounding the outlet properly, or using a GFCI receptacle. (Check local electrical authority and codes.)

What is the "Ground Wire"?

House wiring is color-coded, which allows you to distinguish between the "hot", "neutral" and "ground" wires. The colors are standardized:

- Black or red for hot wires
- White for neutral wires
- Bare copper or green for ground wires

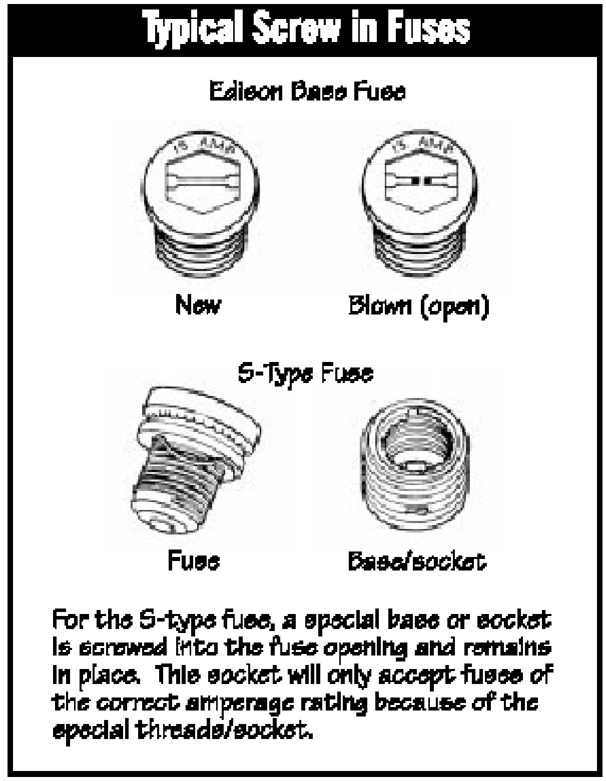
There are some significant differences between the neutral wire and the ground wire. The neutral, or white wire, is responsible for transporting electricity back to a power source after it has passed through a load, or the device using the electricity (such as a light, fridge, stove, etc.). The ground, or copper or green wire, protects the system through the means identified above.

Important!

As a rule of thumb, remember that the ground wire should ALWAYS be the FIRST thing you hook up, and the last thing that you disconnect.

Safety System of a home

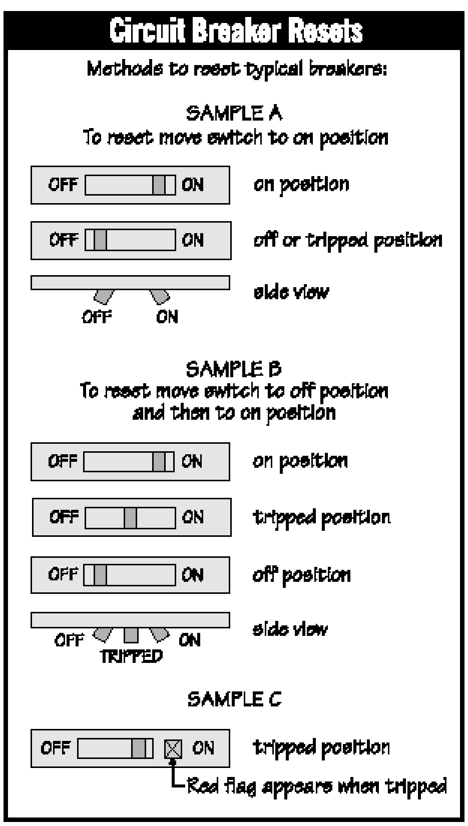
Fuses



The main job of the fuse is to **protect the wiring**. Fuses should be sized and located to protect the wire they are connected to. If a device like your car radio suddenly draws enough current to blow the fuse, the radio is probably already toast. The fuse is there to protect the wire, which would be much harder to replace than the radio.

The idea behind a fuse is to protect a house from an electrical fire. If the hot wire were to accidentally touch the neutral wire for some reason (say, because a mouse chews through the insulation, or someone drives a nail through the wire while hanging a picture, or the vacuum cleaner sucks up an outlet cord and cuts it), an incredible amount of current will flow through the circuit and start heating it up like one of the coils in a toaster. The fuse heats up faster than the wire and burns out before the wire can start a fire.

Circuit Breaker



Circuit breakers are protective device for each circuit, which automatically cuts off power from the main breaker in the event of an overload or short. Only a regulated amount of current can pass through the breaker before it will "trip."

Why You Need a Circuit Breaker

The power distribution grid delivers electricity from a power plant to your house. Inside your house, the electric charge moves in a large circuit, which is composed of many smaller circuits. One end of the circuit, the **hot wire**, leads to the power plant. The other end, called the **neutral wire**, leads to **ground**. Because the hot wire connects to a high energy source, and the neutral wire connects to an electrically neutral source (the earth), there is a voltage across the circuit **-- charge moves whenever the circuit is closed. The current is said to be alternating current, because it rapidly changes direction.**

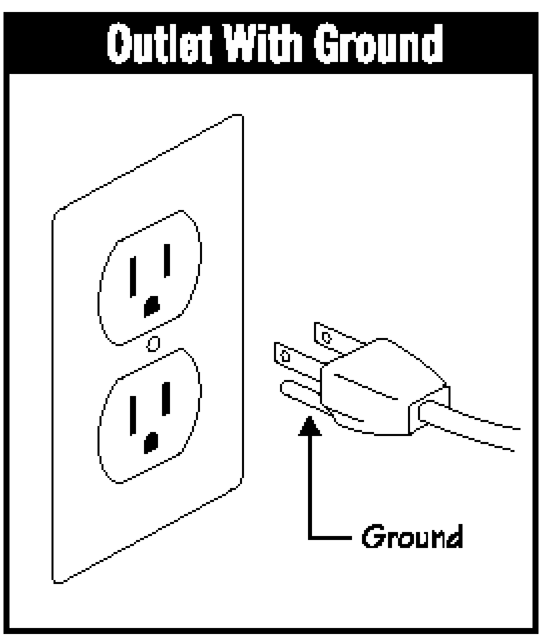
The power distribution grid delivers electricity at a consistent voltage (120 and 240 volts in the United States), but resistance (and therefore current) varies in a house. **All of the different light bulbs and electrical appliances offer a certain amount of resistance, also described as the load**. This resistance is what makes the appliance work. A light bulb, for example, has a filament inside that is very resistant to flowing charge. The charge has to work hard to move along, which heats up the filament, causing it to glow.

In building wiring, the hot wire and the neutral wire never touch directly. The charge running through the circuit always passes through an appliance, which acts as a resistor. In this way, the electrical resistance in appliances limits how much charge can flow through a circuit (with a constant voltage and a constant resistance, the current must also be constant). Appliances are designed to keep current at a relatively low level for safety purposes. Too much charge flowing through a circuit at a particular time would heat the appliance's wires and the building's wiring to unsafe levels, possibly causing a fire.

This keeps the electrical system running smoothly most of the time. But occasionally, something will connect the hot wire directly to the neutral wire or something else leading to ground. For example, a fan motor might overheat and melt, fusing the hot and neutral wires together. Or someone might drive a nail into the wall, accidentally puncturing one of the power lines. When the hot wire is connected directly to ground, there is minimal resistance in the circuit, so the voltage pushes a huge amount of charge through the wire. If this continues, the wires can overheat and start a fire. **The circuit breaker's job is to cut off the circuit whenever the current jumps above a safe level.**

All the wiring in a house runs through a **central circuit breaker panel** (or fuse box panel), usually in the basement or a closet. A typical central panel includes about a dozen circuit breaker switches leading to various circuits in the house. One circuit might include all of the outlets in the living room, and another might include all of the downstairs lighting. Larger appliances, such as a central air conditioning system or a refrigerator, are typically on their own circuit.

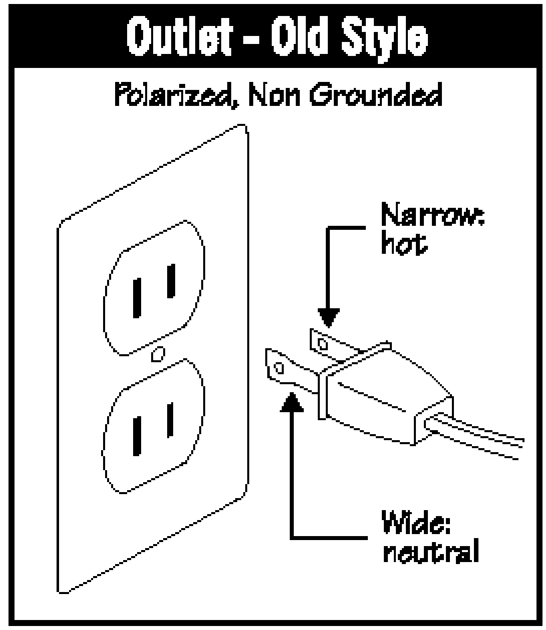
Electrical Polarity



Polarity is an important concept. For safety’s sake, you need to understand the basics.
Electricity circulates through wires just like water moves through a hose. In the case of a lamp, for instance, electricity pushes through the “hot” wire, lights the bulb, and returns through the neutral wire.
Plugs on modern lamps and other devices have one wide blade and one narrow blade so that they can be plugged into an outlet, in the correct position only—unlike plugs on old
lamps, which could be reversed. Electrical devices with three-prong plugs have a ground wire; these, too, can only be plugged into an outlet in one position. You may find a modern electrical tool with a

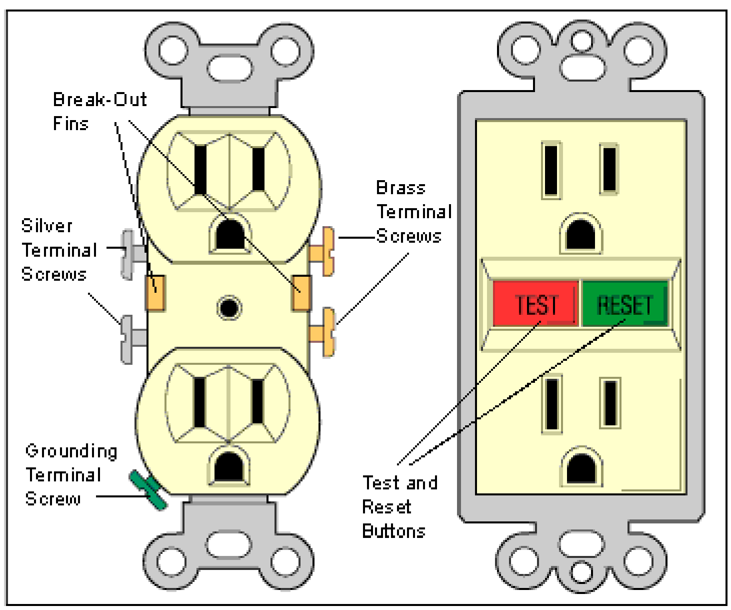
plug that has two narrow blades that can be inserted in either direction. These are special "double insulated" tools with plastic housings that isolate the electrical components from contact with your skin.

What happens if you power a device with "reversed polarity"—that is, with the plug reversed? Stereo equipment may buzz; electrical and computer equipment may be damaged. Lights and lamps pose a serious hazard. When turning off the switch, you would be turning off the neutral (return) wire, not the live (hot) wire. This means that even when the lamp is off, the ring around the base of the bulb is still live, and if you touch the ring you can get a serious shock. What does all this mean to you? Never change a plug or outlet unless you understand polarity and know exactly what you are doing.



Receptacles and Switches

When replacing receptacles and switches remember to wire the new one back in the same way the old one came out! It really can be that simple. Take note of the connections before you disconnect them. Make yourself a sketch of how the switch or receptacle is wired or mark the wires with masking tape and a pencil so you will know how to put them back.



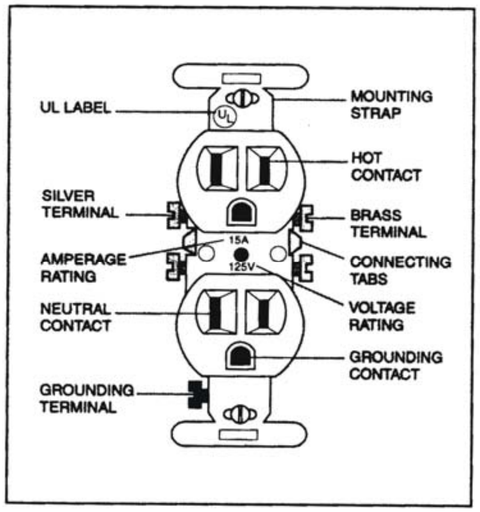
Receptacles (Outlets)

Unlike switches, which come in several different varieties, most receptacles look pretty much the same. There are differences in amperage and voltage ratings. And receptacles may be either CU CLAD or CO/ALR (for aluminum) rated.

A standard duplex receptacle has two outlets for receiving plugs. Each outlet has a long (neutral) slot, a shorter (hot) slot, and a half-round grounding hole. This ensures that the plug will be polarized and grounded. Receptacles are rated for maximum amps. A 20-amp grounded receptacle has a T-shaped neutral slot; use it only on 20-amp circuits. For most purposes, a 15-amp grounded receptacle is sufficient. When replacing a receptacle in an ungrounded outlet box, use a 15-amp ungrounded receptacle, intended only for use in older homes without ground wires in the circuits. Use a three-pronged plug adapter on an ungrounded receptacle only if the wall-plate screw is grounded. The switch in a combination switch/receptacle can be hooked up to control the receptacle it's paired with. A 20-amp single grounded receptacle makes it nearly impossible to overload a critical circuit. For outdoors, in basements, or within 6 feet of water fixture, install ground-fault circuit-interrupter (GFCI) receptacles. Select a 240-volt receptacle based on the appliance amperage rating. Plugs required for appliances of 15, 20, 30, and 50 amps will have different prong configurations.

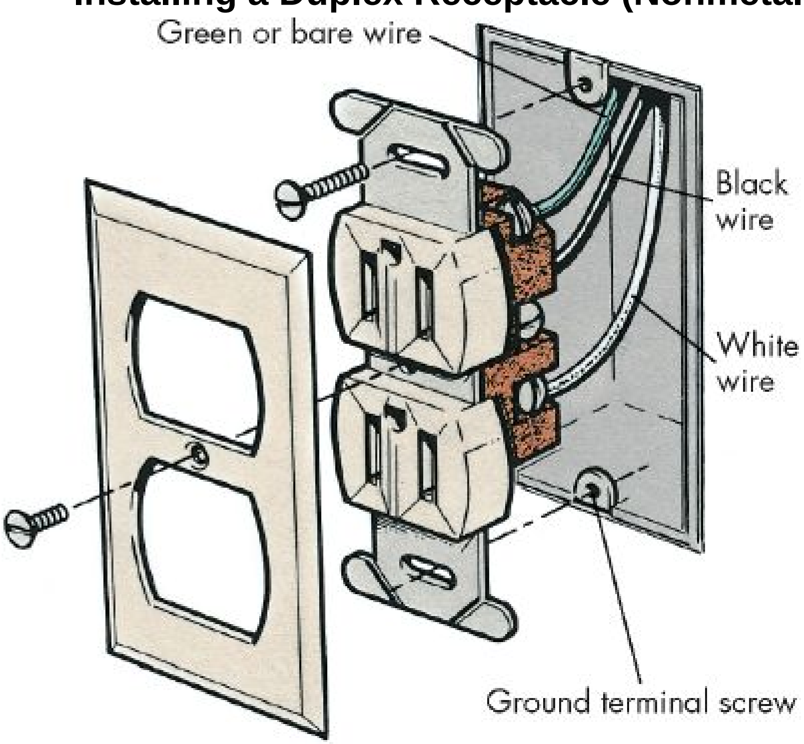
General Purpose Receptacle

The most common type of receptacle found in residential installations for general purpose circuits is the duplex receptacle. The receptacle consists of two halves, each designed to receive a three-contact plug. Each half is equipped with a short contact, which receives the hot conductor, and a long contact, which receives the grounded circuit conductor. Each half also has a u-shaped grounding contact which receives the grounding conductor. Each half of the receptacle is also equipped with a silver screw terminal and a brass screw terminal for conductor connections. A green grounding screw terminal is usually located on the lower half of the receptacle.



Before connecting a receptacle – or any electrical device – to a circuit, always check the device to make sure it is properly rated for its designated use. Make sure that you are using only listed receptacles. Most receptacles used in today's newer homes are rated for and labeled for use with copper conductors only. Manufacturers place this information directly on the device .

Installing a Duplex Receptacle (Nonmetallic Device Box)



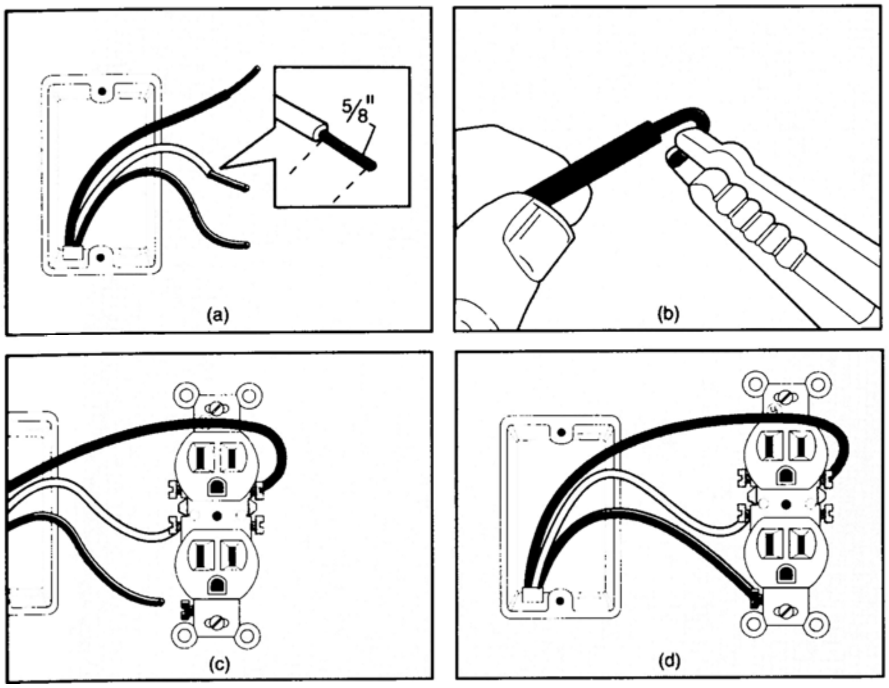
Remove approximately 5/8 – inch from both insulated conductors.

Using an electrician's tool or needle-nose pliers, make a loop at the end of the black, white, and grounding conductors,

Place the looped end of the black (hot) conductor under the brass screw terminal on the receptacle. Pull the loop snug around the screw terminal and tighten with a screwdriver.

Invert the looped end of the white conductor under the silver screw terminal on the opposite side of the switch and tighten. No bare wire should be exposed.

Complete the installation by connecting the grounding conductor to the green terminal on the receptacle.



Installing conductors on a duplex receptacle in a nonmetallic device box. (a) Remove the conductor insulation (b) Make a loop at the end of the conductors. (c) Connect the black conductor the brass terminal and the white conductor to the silver terminal. (d) Connect the grounding conductor to the receptacle ground.

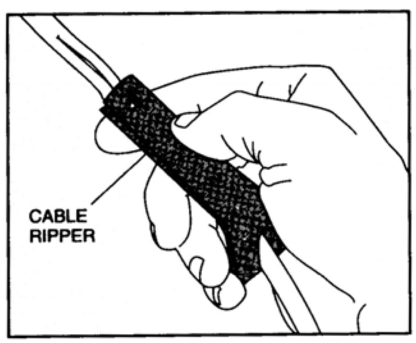


Figure 6-F-1. *Slice the cable sheathing with a cable ripper.*

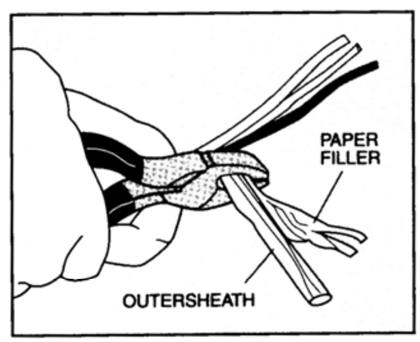


Figure 6-F-2. *Remove the outer sheathing and inner paper lining.*

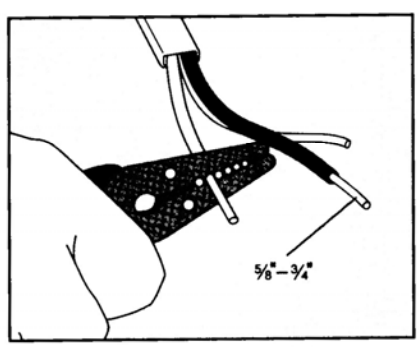


Figure 6-F-3. *Remove 5/8 to 3/4 inches of insulation from each conductor.*

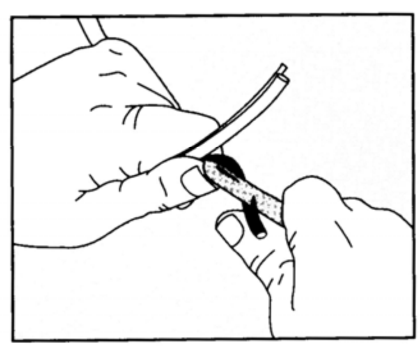


Figure 6-F-4. *Do not damage the conductor when removing the insulation.*

Ground Fault Circuit Interrupter (GFCI) Receptacles

Ground Fault Circuit Interrupters should be installed in circuits which are located in potentially wet areas such as kitchens, bathrooms, garages, workshops and outdoor locations. Although they are now required by code in such areas, older homes were built without them. They are inexpensive, easy to install and they may save your life!

> Electricity always wants to find a ground, and it attempts to reach that ground in the shortest route possible. A ground fault is a short circuit in which current travels through a path you don't want it to in order to find a ground. The path could be you! Being wet causes you to be a better electrical conductor, and this is the reason damp locations should have a GFCI receptacle at the beginning of the circuit. GFCI's monitor the current going to and coming from the receptacle. Within a fraction of a second of detecting a current imbalance, a properly installed GFCI shuts that circuit down. You may get shocked, but you should be safe from electrocution. All receptacles installed in line after the GFCI are also protected.
>
> GFCI's have test and reset buttons. Once the circuit has been broken, the receptacles in line after the GFCI will not work until it has been reset. So, in the room you are trying to protect, install the GFCI in the receptacle closest to the service panel end of the house. Hopefully, this will be closer to the beginning of the circuit. Then, to determine which receptacles are protected by the GFCI, restore the power and push the test button. The GFCI receptacle and any others that follow it in the circuit will be dead. If you are lucky, that will include all of the other receptacles in the room. If the other receptacles you wish to protect are still active, turn off the power to the circuit, remove the GFCI, and install it in place of another receptacle on the other side of the room. Retest as before.

GFCI receptacles may come with wire leads instead of screw terminals. The leads are connected to the wires with plastic wire nuts. When you look at a normal 120-volt outlet in the United States, there are two vertical slots and then a round hole centered below them. The left slot is slightly larger than the right. The left slot is called "neutral," the right slot is called "hot" and the hole below them is called "ground." If an appliance is working properly, all electricity that the appliance uses will flow from hot to neutral. A GFCI **monitors the amount of current flowing from hot to neutral**. If there is any **imbalance**, it **trips the circuit. It is able to sense a mismatch as small as 4 or 5 milliamps, and it can react as quickly as one-thirtieth of a second.**

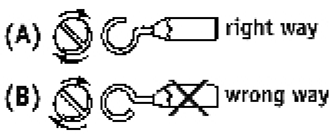
So let's say you are outside with your power drill and it is raining. You are standing on the ground, and since the drill is wet there is a path from the hot wire inside the drill through you to ground. If electricity flows from hot to ground through you, it could be fatal. The GFCI can sense the current flowing through you because not all of the current is flowing from hot to neutral as it expects -- some of it is flowing through you to ground. As soon as the GFCI senses that, it trips the circuit and cuts off the electricity.

Basic Switch Types

Replace switches with replacements of the same type. For example, a single pole decorator switch will directly replace a conventional single pole switch. You cannot replace a three way switch with a single pole switch. Replacement switches should also be of the same amperage and voltage ratings as those they replace.

Single Pole Switches

Single pole switches are the simplest and most often used switches. They are used to switch receptacles or fixtures from a single location. So, unless you can turn on a light or a series of receptacles from more than one place in your home, it should be wired with a single pole switch. These switches have on and off markings, and should be installed so the “on” marking faces up.



The single-pole toggle switch has two brass terminal screws. One wire (usually the black) is cut, then, is connected to the two brass terminals. The other wire (white) is uninterrupted from the power source to the light or fixture.

When connecting a wire to the terminal screw of a switch, always turn the loop on the end of the wire in the same direction as the screw threads, as shown in part A of this image. If the loop is turned in the opposite direction (part B), tightening the screw will loosen the loop. If the wire connects to the terminal screw and then runs on, cut and strip the wire on both sides of the cut. Using a 6" piece of wire with both ends stripped (sometimes called a pigtail) and a wirenut, fasten the three wires together. Connect the pigtail to the terminal. Use wirenuts or screw-on connectors to save time and effort when you must make a splice in any electrical wire. Always cover any soldered connection with insulating tape. If soldered sections are rough, apply an extra layer of tape. Insulate the wire an additional inch or two beyond the soldered connection in each direction.

White wires should generally be attached to light colored terminal screws such as silver. Black wires should generally be attached to dark colored screws such as brass colored. If the terminal screws are the same color, either wire can generally be attached to either terminal. Green terminal screws are for grounding wires.

Double Pole Switches

Double pole switches work like single pole switches except that they can receive two hot wires. For this reason, they are often used as switches for 240-volt receptacles and appliances. These switches have on and off markings, and should be installed so the “on” marking faces up.

Three-Way Switches - Three-way switches allow you to turn a light on and off from two different locations, such as at the top or the bottom of a stairway.

Three-way switches are usually used to provide two separate switching points for a single fixture. These switches must always be installed in pairs and do not have on and off markings. Three-way switches have three screw terminals. One of the terminals is darker than the others and is called the common screw terminal. When replacing these switches, be sure to mark the common wire before removing the old switch so you'll know which wire to hook to this terminal. The other two terminals are called traveler terminals. Each of the two remaining wires can be attached to either of these terminals. It doesn't matter which wire goes to which terminal.

Dimmer Switches

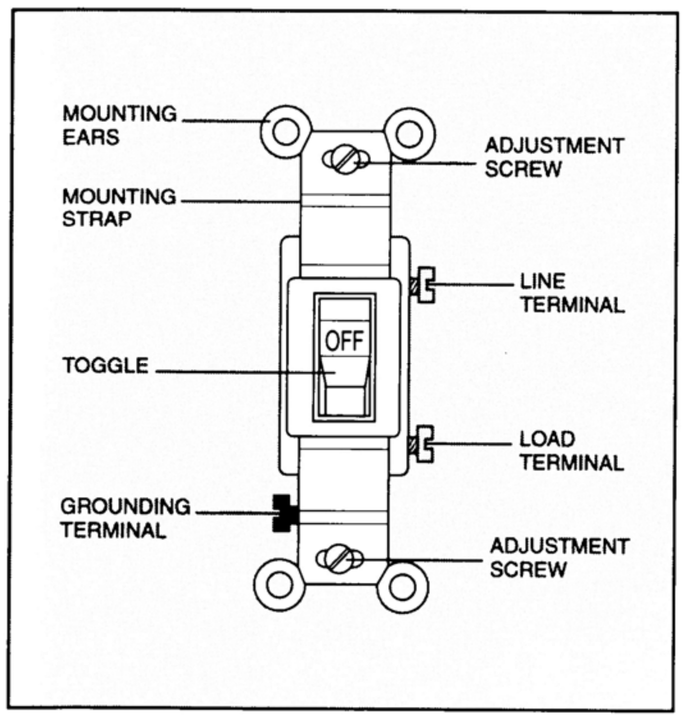
These specialty switches allow you to increase or decrease the brightness of an incandescent light. They come in single pole and three-way models and can be used for incandescent lights only. Dimmers can come with control knobs, sliders or toggles. When choosing a dimmer, be sure that your fixture wattage does not exceed that which can be handled by the dimmer.

Receptacle Switches

Receptacle switches allow you to have both a switch and a receptacle in one box. These switches must be wired into the middle of a circuit. They have one silver terminal, and three darker ones. The incoming hot wire (black) is attached to a terminal on the side where two brass terminals are connected with a tab. The black wire going to the fixture is attached to the copper terminal on the side which has both a copper and silver colored terminal. The two white wires are pigtailed together and to the silver terminal. A ground wire is pigtailed to the other ground wires and the metal box ground terminal.

How Switches Work

Switches, like receptacles, are designed to perform a specific function in controlling the electricity at the outlet.



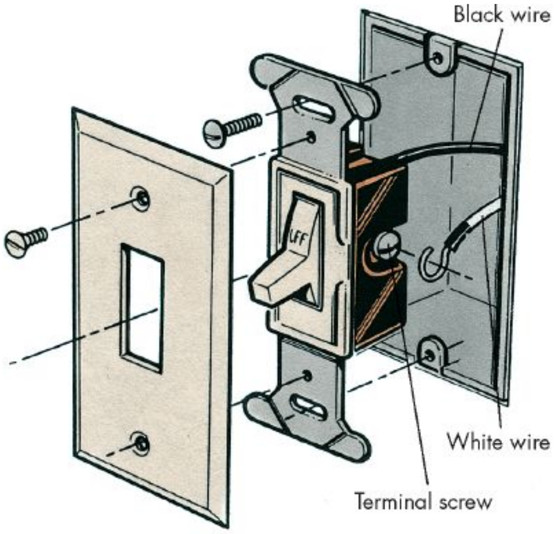
Switch Toggle -- controls switch to an “ON” or “OFF” position when moved up or down. When the switch is properly mounted, the “ON” marking on the toggle will be visible when the toggle is pushed to the “UP” position.

Switch Terminals – screw connections for cable conductors. Screw terminal locations on the switch may vary depending on manufacturer. The top terminal on the switch is also known as the line or input terminal and the bottom terminal is known as the load terminal.

Grounding Screw Terminal – provides connection for grounding conductor. Usually green in color, and the location on the switch varies.

Installing a Single-pole Switch to a Fixture with the Power Source Cable Entering at the Switch

The power source cable connects the switch to the over current protection device in the SEP or subpanel. The remaining cable connects the switch to the lighting fixture.
Always begin the installation by connecting the white conductor to the silver screw terminal on the lighting fixture (load).

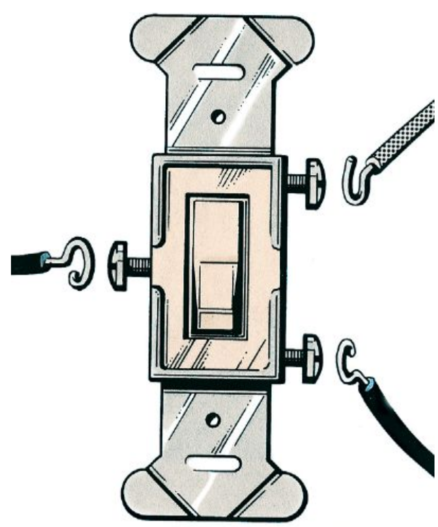


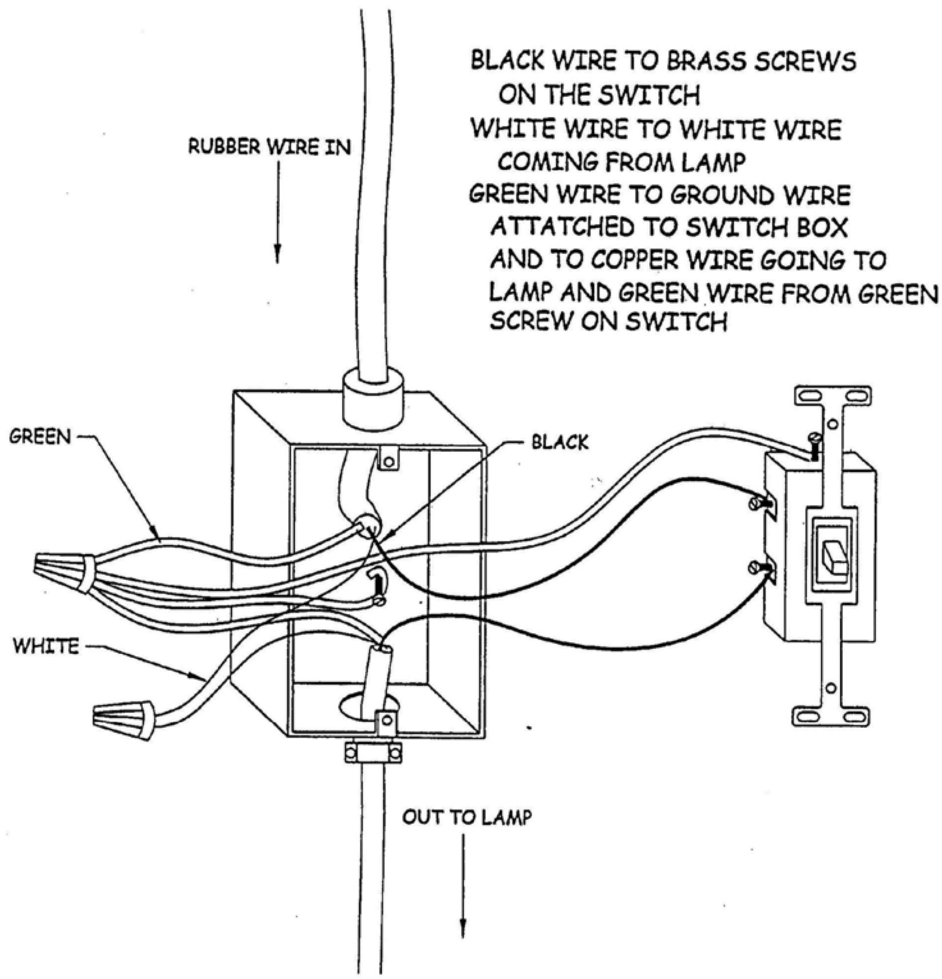
Connect the black (hot) conductor to the brass screw terminal on the lighting fixture.
Because the installation is made using a nonmetallic outlet box, fold the grounding conductor into the outlet box. Do not remove.

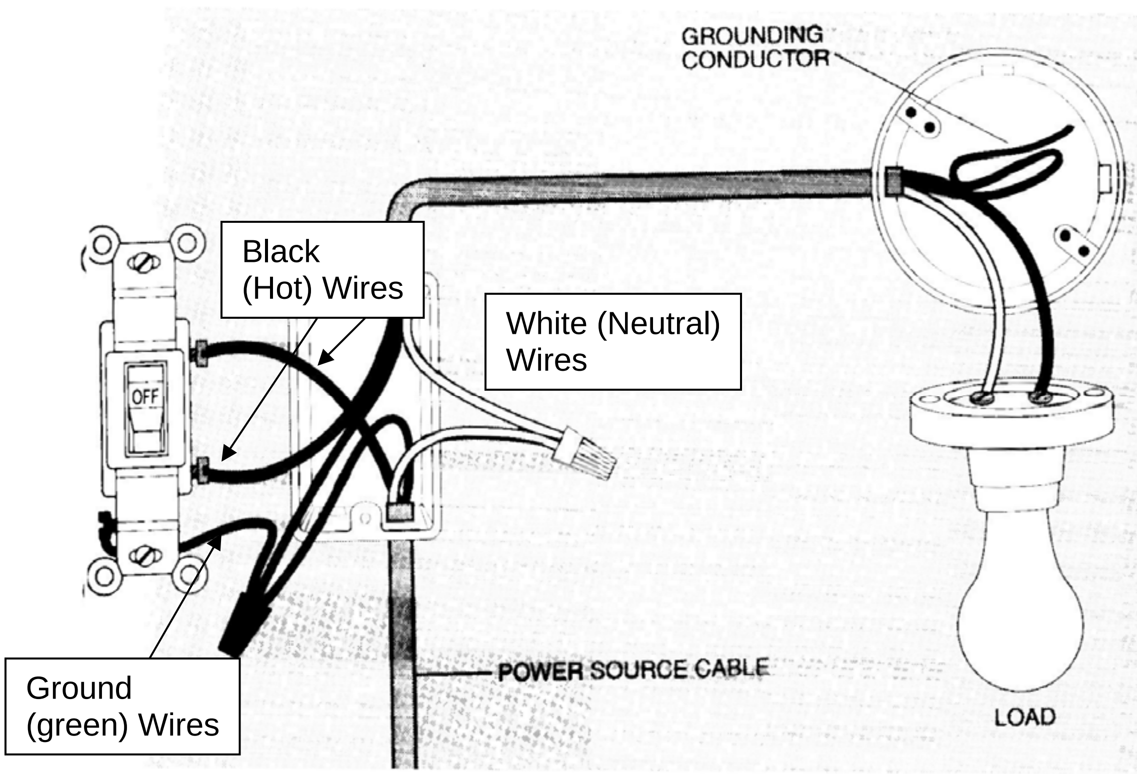
Switch Connections
Connect the black (hot) conductor in the power source cable to the top terminal on the switch.
Connect the black (hot) conductor in the cable from the lighting outlet to the bottom terminal on t he switch.

Using a wire nut, connect the white conductors from both cables.
Using a pigtail, connect all grounding conductors to the grounding terminal on the switch.

All switches work on the same general principles, and you can usually choose a switch with features you like best. The single-pole toggle switch is still the most popular. When the toggle switch is mounted properly, the words ON and OFF are upright on the toggle lever, and the light goes on when you flip the switch up. A variation of the traditional toggle switch is the lever-action switch, which lies almost flush with the wall. It turns the fixture on when someone pushes the top of the switch in. The push-button switch has a single button that turns the light on when pressed and off when pressed again. Some switches are available with the extra feature of a built-in neon lamp that glows when the switch is off, making it easy to locate the switch in the dark. Dimmer switches, with a dial to control the brightness, turn the light off when the dial is turned all the way down or pushed in. Some dimmer switches are like toggle types. Sliding the toggle upward increases the light's intensity; sliding it all the way down turns off the light. You can install these switches as replacements for nearly any type of switch.




BLACK WIRE TO BRASS SCREWS
ON THE SWITCH
WHITE WIRE TO WHITE WIRE
COMING FROM LAMP
GREEN WIRE TO GROUND WIRE
ATTATCHED TO SWITCH BOX
AND TO COPPER WIRE GOING TO
LAMP AND GREEN WIRE FROM GREEN
SCREW ON SWITCH
RUBBER WIRE IN
GREEN
BLACK
WHITE
OUT TO LAMP



How to Wire – A basic light circuit controlled by a single pole switch using the components found in the Maine Public Service Electrical Wiring KIt

A single-pole switch installation controlling a light fixture. The power source enters at the switch outlet.

1. Always begin the installation by connecting the white conductor to the silver screw terminal on the lighting fixture (load).
2. Connect the Black (hot) conductor to the brass screw terminal on the lighting fixture.
3. Because the installation is made using a nonmetallic outlet box, fold the grounding conductor into the outlet box. Do not remove.
4. Connect the black (hot) conductor in the power source cable to the top terminal on the switch.
5. Connect the black (hot) conductor in the cable from the lighting outlet to the bottom terminal on the switch.

Using a wire nut, connect the white conductors from both cables.

6. Using a pigtail, connect all grounding conductors to the grounding terminal on the switch.

Sizing Junction Boxes

All switches and outlets (receptacles) need a properly-sized junction (electrical) box. For example, a 2" x 3" box with 3 wires (14 gauge) should be

2 1/2" deep. The same box with 5 wires must be 3 1/2" deep. Installing an undersized box is probably the most common wiring mistake for do-it-yourselfers. When in doubt, it's usually best to use a larger box. Overcrowd a box and you risk damaging wire connectors, piercing insulation, and cracking a switch or receptacle, any of which could cause a short. That is why codes spell out how many wires you can install in a box.

If you're not sure about box size requirements, remember to ask your electrical inspector when submitting diagrams.

Here's one way to calculate minimum box size:

1. Count the **number of wires** for the box. Don't count outlet/switch pigtails and count all ground wires as one.

2. Take that number; add **one** for each **cable clamp**, and **two** for each **device** (like a switch or outlet).

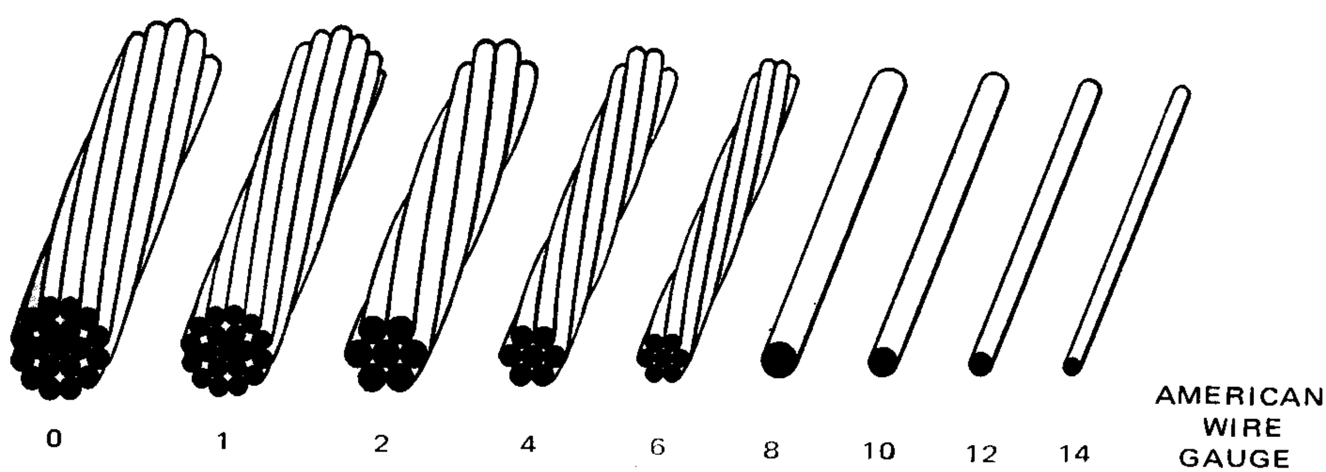
3. If the box contains only 14-gauge wires, **multiply** the total by 2 cubic inches. Or, for 12-gauge wires, multiply the total by 2.25 cubic inches.

The result is the minimum allowable volume the box should be. Volumes are usually stamped into the back of the box on the inside.

In a typical room, **place switch boxes 48-50 inches above the floor and receptacles 12-16 inches above floor level. Check with local codes to see how many receptacles you will need. In most cases they must be placed so that no point along any wall is more than 6 feet from a receptacle. This means that you will have to install at least one receptacle every 12 feet along the wall.** For kitchens and bathrooms, GFCI's must be used.

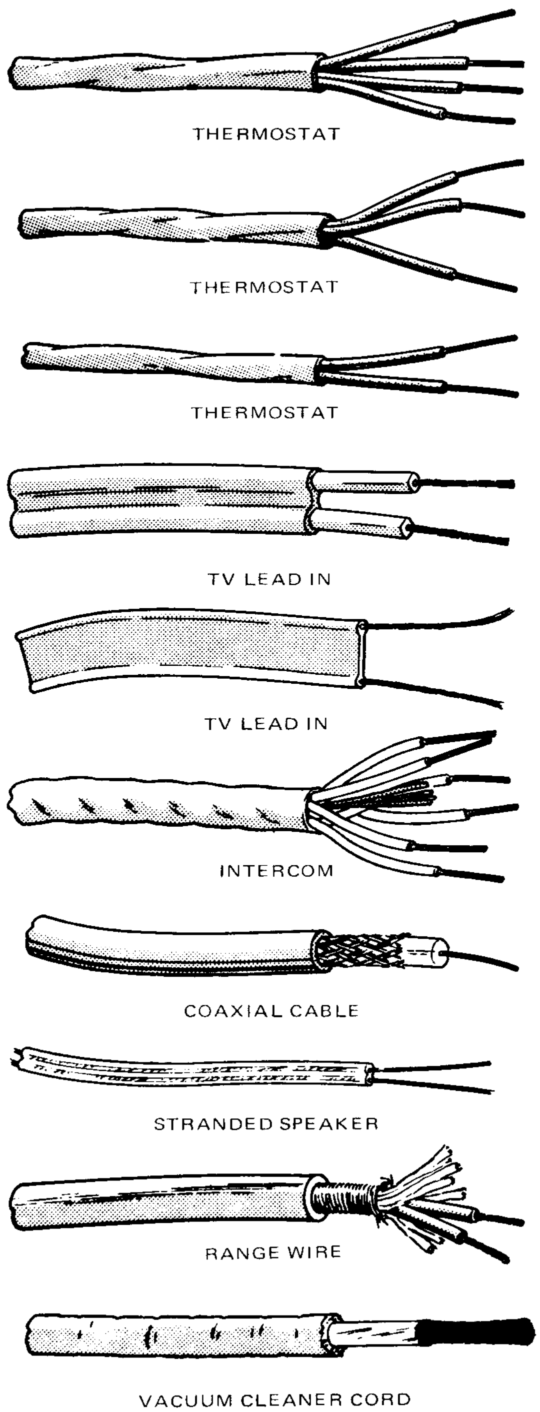
Wire Size

In house wiring, electrical conductors which provide paths for the flow of electric current, are wires over which an insulating material is formed. Insulation is a noncurrent-carrying material which insures that the current flow will be through the wire. Different gauge wires carry different amounts of electricity – 14-gauge carries a maximum of 15 amps, 12-gauge carries up to 20 amps, and 10-gauge wire up to 30 amps. Unsheathed wires are pulled through flexible or rigid conduits. Flexible metal conduits, or Greenfield,



looks like armored cable but doesn't contain wires. It is cut to length, wires are pulled through it, and the completed pieces installed. With conduit, you pull wires through it after it's installed. Doorbells and other low-voltage circuits typically use 18-gauge wire.

Note that, as the numbers become larger, the size of the wire decreases. For most house wiring jobs, copper wire numbers 12 and 14 are specified by the building plans. Numbers 6 and 8 wires, which are available either as solid wire, or stranded, are used for heavy power circuits, and as service entrance leads into buildings. See Unit 2, pages 12-18 in _House Wiring Simplified_ for more information on conductors.



Wire Colors

White: Neutral, carrying power back to the service panel
Black: Hot, carrying power from the service panel
Red and other colors: Also hot, color-coded to help identify which circuit they are on
White with black tape: A white wire that is being used as a hot wire
Bare or green: A ground wire

Special purpose Cords

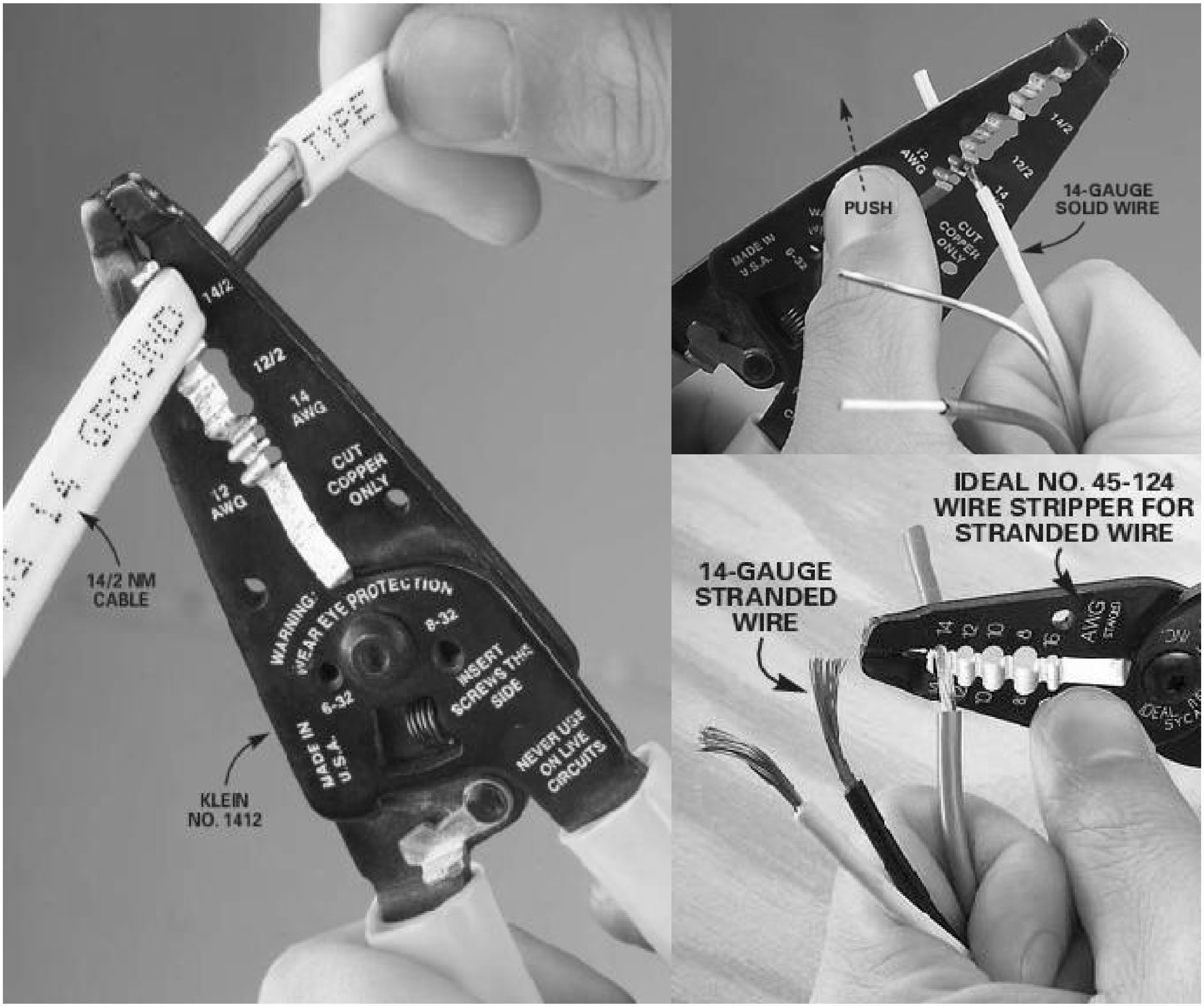
All house wiring must be installed in accordance with City and State Codes or regulations applicable to the work being done, also the National Electric Code.
Maine Public Service requirements must also be met.

Compliance with Codes usually results in installations free from electrical hazards, but the systems will not necessarily be efficient, convenient, or adequate for good service and future expansion.

When doing house wiring, only Underwriters Laboratories (UL) approved materials and devices should be used. All wiring and fixtures should be installed in a neat, exacting manner, closely following plans provided for the job.

As you progress with the house wiring activities, you will find that many other types of conductors are available.

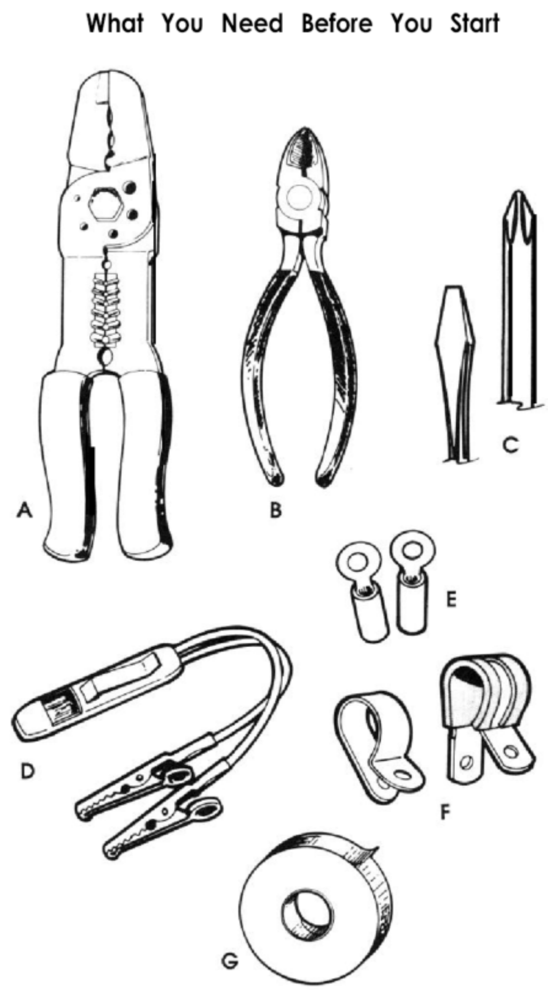
Stripping Wire



The easiest way to remove plastic sheathing from nonmetallic sheathed cable is to use an inexpensive cable ripper. Slip 6 to 8 inches of cable into the ripper's jaws, squeeze, and pull. This slits open the sheathing without damaging the insulation of internal wires. The same job can be done with a knife, but you must be careful: Run the blade right down the middle so it doesn't strip insulation from the wires. Pull back the sheathing you have just slit, as well as the paper wrapping or strips of thin plastic, if any. You'll find two or three separately insulated wires, as well as a bare ground wire. To strip insulation from wires, use a combination tool, which has separate holes for the different sizes of wires. Locate the wire in the correct hole, clamp down, give it a twist, and pull the tool away from you.

TOOLS NEEDED FOR THE JOB!

Pictured are some of the basic tools and supplies that make wiring an easy task. In addition to the items shown, you may have occasion to use an electric drill and a saber saw.



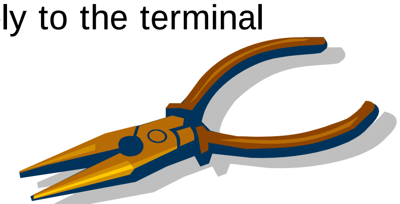
A. Multipurpose Tool. This tool allows the insulation to be easily stripped from wires without damaging the wire conductors. The same tool is used to cut wire and to crimp the insulated, solderless connectors on to the wire. For optimum connections, the crimping tool should be compatible with the insulated connector (tool and connector from the same manufacturer).

B. Wire Cutters. This form of pliers is strictly used for cutting wire conductors. Their shape and design makes them ideal for performing clean, even cuts of multi-stranded marine wire.

C. Screwdrivers. Both Phillips head and straight slot screwdrivers.

D. Tester. To check that all current is off before you begin to work on AC electrical items.

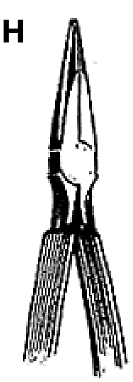
E. Crimp-on Connectors. Available in a variety of wire and stud sizes, these connectors crimp on to multi-stranded wire and fasten securely to the terminal screws of receptacles and breakers.



F. Cable Clamps and Support Clips. Available now in nylon or metal with rubber insulation, cable clamps are an effective way to support wiring.

G. Electrical Tape. It is a good practice to apply electrical tape around the wire and the insulation of the crimp-on connector to prevent moisture from entering the connection. Electrical "tracer" tape comes in a variety of colors and can be used to identify various circuits.

H



H. Long-nose Pliers. Handy in tight spaces, this tool has rounded jaws to aid in bending wires to fit around screw terminals.

Electrical Encyclopedia

Alternating Current: Current that flows in first one direction, then the other in a circuit. The current that flows through lights, motor driven equipment and appliances such as refrigerators, heating appliances, electronic devices and equipment in the home.

Aluminum Wiring: It is often used for the service entrance conductors and for large gauge wiring to major appliances such as electric clothes dryers, central air-conditioning, electric oven, etc. Aluminum wiring for such applications is quite satisfactory; however, aluminum wiring installed as branch circuits for general lighting, electrical switches and receptacle outlets, small appliances, etc. may be hazardous and certain modifications are recommended for these applications.

Ampere: Amperes, or amps, is a measure of the capacity of an electrical system. Electron flow (current) along a conductor. When 6.28 quintillion electrons pass any particular point in a circuit in one second, this is called an ampere or amp. Abbreviated "A" or "I" (intensity of current). The typical minimum requirement is 100 amps; if a home is larger, or has central air-conditioning or electric heat, 150 to 200 amps are recommended.

Branch Circuit: A branch circuit is the wiring from a fuse or circuit breaker in an electrical service panel that provides electricity to particular electrical switches, outlets, junction boxes, etc.

BX Wiring: BX wiring, or armored cable, is a type of wiring that is installed in a house. This type of wiring is enclosed in a metallic sheathing and is more resistant to damage than Romex wiring.

Circuit: An electrical circuit is a flow of electricity from a supply source to one or more terminals, such as electrical outlets, switches, appliances, etc. A closed circuit is one in which the electricity is flowing, lighting a light, running a motor, or some other appliance. The circuit runs all the way from the power source (the place the electricity is being generated) to your home, through the appliance or light bulb, and back to the generator.

Circuit Breaker: An over current protection device that is designed to automatically cut off the flow of electricity when the flow of current through the circuit breaker exceeds its rated capacity. Unlike most fuses which require replacement when they are overloaded, a circuit breaker can be reset much like a switch.

Conductor: A conductor is a wire that conveys electricity – allows electrons to move readily offering low resistance...

Copper Wiring: Copper wiring is the most common type of metal used for wiring and can be either BX or Romex or enclosed in conduit.

Current (or flow of current): The continuous flow of electrons in a circuit (in a conductor) measured in amperes.

Direct Current: Current that flows in only one direction in a circuit. This type of current is used in flashlights, portable radios, cameras, boats and automobiles.

Distribution Lines: Electric hues that deliver electricity from a step-down distribution substation or step-down distribution transformer to the final step-down transformer at the customer's premises.

Doubled-Up Conductors: One conductor should be terminated on a service panel fuse or circuit breaker lug unless the lug is specially designed to accept more than one conductor; all improper double connections must be eliminated by a licensed electrician by relocating the affected conductors to a new position in the service panel.

Electric Meter: This is an instrument designed for measuring the amount of electrical power consumed by the consumer in KILOWATT hours (kWhs).

Electrical Fault: Unsafe condition that occurs when there is a break in the insulation of a conductor or appliance permitting the appliance and any attached equipment to become energized.

Electricity: The flow of electrons from one atom to another.

Electron: A very small negatively charged particle which can flow from one atom to another in a conducting material.

Fuse: An over current protection safety device that is designed to automatically cut off the flow of electricity when the flow of current through the fuse exceeds its rated capacity.

Ground Fault Circuit Interrupter: Ground fault circuit interrupters, GFCI units, are installed in areas that are subject to water, such as bathrooms, kitchens, garages, unfinished basements, outdoors, etc. GFCI units are designed to protect persons from hazardous ground faults by automatically turning off the electricity to the unit when a fault is detected.

Ground: Electrical systems must be properly grounded to provide a safe service. System conductors are typically secured to driven ground rods or water service pipes.

Hertz: The current flow with voltage fluctuations is called a cycle. In the U.S., 60 of these cycles occur each second, thus, the term 60-cycle AC. The term for “cycles per second” is Hertz or “HZ”.

Hot (Delivery) Line: Wire bringing negatively charged electrons from the electrical source to the point of use. A complete circuit must have a delivery wire or conductor and a return wire or conductor.

Knockouts: Knockouts, or twist outs, in an electrical service panel should not be removed unless the position is filled; missing knockouts present a safety hazard if a person places a finger into the service panel through the knockout. Therefore, all missing knockouts should be replaced with plastic fillers or with circuit breakers.

KVA: 1,000 x volts x amps.

Kilo: A metric term meaning 1,000.

Kilowatt-hour: Unit used for metering and selling electricity. Unit of power (1,000 watts) used in an hour (unit of time). Abbreviated kWh.

Knob-and-Tube Wiring: Knob-and tube wiring is an outdated type of wiring that has been replaced by Romex and BX wiring. This outdated type of wiring can be hazardous and replacement with modern wiring is typically recommended.

Lightning: Life threatening condition caused by the imbalance of electrons in the atmosphere between positively and negatively charged atoms.

National Electric Code (NEC): Published minimum standards to encourage effective safe electric wiring procedures, types of materials, sizes of components which, if followed, can enhance quality of life, and in particular electrical safety. It has been developed to provide uniform, minimum standards for the electrical industry.

Nameplate: A metal or plastic label attached to a motor or appliance providing information such as rating in amperes, volts, watts, hertz, horsepower, manufacturer, model number, serial number, etc.

Neutral (return) Line: Wire (conductor) returning current from the point of use at zero voltage (pressure) to the electrical power source.

Ohm: A unit of electrical resistance (the energy required to force electrons from one atom to the next) in a conductor. Abbreviated as "R", for resistance.

Ohm's Law: An easy way to remember the relationship between amp, volts, and ohms is the Ohm's Law (E= I X R) (I = E/R or R = E/I); that is, Volts = Current X Ohms or, the current flowing in a circuit is directly proportional to the voltage and inversely proportional to the resistance. Current flow in a circuit increases as the voltage is increased, and decreases as the resistance in increased.

Open Ground: An electrical receptacle outlet with an open ground condition is an outlet with an improper wiring condition and such conditions may be hazardous and repair is required.

Open Junction Box: Electrical junction boxes must have proper covers; when a junction box does not have a cover; it is noted as an open junction box.

Over Fused Circuit: An over fused circuit is a circuit that is protected from over current by a fuse or circuit breaker that is over sized for the capacity of the circuit conductors. This is a hazardous condition that can result in overheating of the conductors and may result in an electrical fire.

Overhead Distribution: Traditional way of distributing electricity using wires attached to poles above the ground rather than underground.

Overhead Service: An overhead electrical service is a service where the conductors approach a home overhead.

Over Loaded Circuit: An overloaded circuit is a branch circuit that has too many electrical outlets, switches, etc. connected to it and therefore, the fuse or circuit breaker associated with this circuit is likely to trip. An overloaded circuit may have to be split into two circuits if the fuse blows or the circuit breaker trips too often.

Parallel Circuit: A circuit that provides for dividing the current flow to each light or appliance on the circuit. If one light bums out, current will continue to flow and function in other lights on the circuit.

Pigtail: Short wire (conductor) used for connecting two or more conductors to a single screw terminal on a receptacle. Also called a jumper.

Primary Distribution Lines: Power lines that distribute electric energy with voltages ranging from 2,300 to 34,000 volts.

Receptacles: Provide easy plug-in access to the electrical power referred to as convenience outlets or wall outlets.

Reversed Polarity: An electrical receptacle outlet with a reversed polarity condition is an outlet with an improper wiring condition and such conditions may be hazardous and repair is required.

Romex Wiring: Romex wiring, or nonmetallic sheathed wiring, is a type of wiring that is installed in a house. This type of wiring is widely utilized but is less resistant to damage than BX wiring.

Residential Rate: A schedule of charges for the amount of electricity used in a month. Designed for homes, small businesses and farms.

Resistance: The energy required to force electrons from one atom to the next in a conductor (wire). Measured in ohms. High resistance to conductivity can result in excess, dangerous heat in wiring.

Secondary Distribution Lines: Power lines that branch off from primary distribution lines carrying electricity with voltages ranging from 120 to 575 volts.

SEER: Seasonal Energy Efficiency Ratio. A sticker affixed to heating and air conditioning equipment indicating a numerical rating showing the relationship between the output of a given piece of equipment to the amount of input energy.

Semi-conductor: A substance that is neither a good conductor nor a good insulator. The free electrons are held rather tightly posing resistance to current flow, producing heat for cooking, heating water, drying hair and clothing, etc.

Series Circuit: A circuit in which all of the current flows throughout the entire circuit. If one light in this type of circuit burns out, the circuit is broken and other lights on the circuit will not operate.

Service: The conductors and equipment for delivering electricity from the electrical supply system to the wiring system of a house.

Service Drop: A service drop is the electrical service lines which run from a utility's distribution cables into a customer's home or place of business. Service drops are typically composed of two 120-volt lines whose output can be combined to produce a 240-vold feed, and a neutral third line. When these three lines are used in the same cable run, they are referred to as triplex cable.

Service Entrance: Also called the weatherhead, is the point of entry for electrical service from the electric utility deliverer to the residence.

Service Panel: The service panel is the center of the electrical service in the house; the service panel is the location of the electrical circuit breakers or fuses. It is also the termination point for all branch circuits in the wiring system of the home.

Short Circuit: An improper connection between the hot and neutral wires of a circuit can result in a short circuit defect. Occurs when 2 conductors come in contact with each other without going through an appliance, thereby reducing the work done and increasing current flow to a dangerous level.

Single-phase Power: Power supplied to homes and small businesses through one transformer, two delivery wires and one neutral (return) wire

Subpanel: Provides additional branch circuit space to the system and reduces the need for long circuit runs.

Switches: Devices that control electrical current that passes through them. They are commonly used for controlling lighting and small and large residential appliances and equipment.

Step-down Transformers: Transformers that are designed to decrease the transmission and distribution voltage and increase the amperage for users.

Step-up Transformers: Transformers that are used at the power plant to increase the voltage and decrease the amperage, lessening the power loss in transmission and distribution lines.

Substation: A group of step-up or step-down transformers.

Surge Protector: Device to protect electrical equipment from damage due to power surges or spikes of electricity and lightning.

Three-phase Power: Three phase power is commonly used by industry for the operation of larger electric motors. Three-phase service is supplied through two or three transformers and four wires.

Transfer Switch: A special switch used in conjunction with the installation of a standby generator. It is designed to prevent the flow of electricity into the utility's lines while the generator is in use.

Transformer: A device used to change voltage and amperage on line, either up or down. See step-up/step-down transformers.

Transmission Lines: Electric power lines used to move large quantities of electricity at high voltages for long distances from the generator to the distribution lines of the local utility system.

Turbine Wheel: A device, usually powered by steam or water, used to spin an electric generator.

Underground Distribution: Electric distribution method using underground lines to enter the building. They are connected to transformers located either above or at ground level.

Underwriters Laboratories: A research and testing organization that tests electrical wiring materials to determine if electrical products meet minimum standards for safety and quality. You should always look for the UL mark of approval when buying or using electrical materials and equipment.

Volt: A unit of electric pressure. The pressure applied to force electrons through the circuit. The pressure that makes electrons move when an appliance starts or a light is turned on. Generally referred to as voltage, this pressure is available in live (hot) wiring circuits whether or not the equipment is turned on. Abbreviated "V" or "E" (electromotive force). Most home wiring is 110 volts; 220 volts is utilized for large appliances such as electric ranges, electric clothes dryers, central air-conditioning, large room air-conditioners, etc.

Voltage: Force used to conduct electrons along a wire (conductor). As electrical current passes through a load, voltage drop results.

Voltmeter: A gauge or device for measuring volts (electrical pressure).

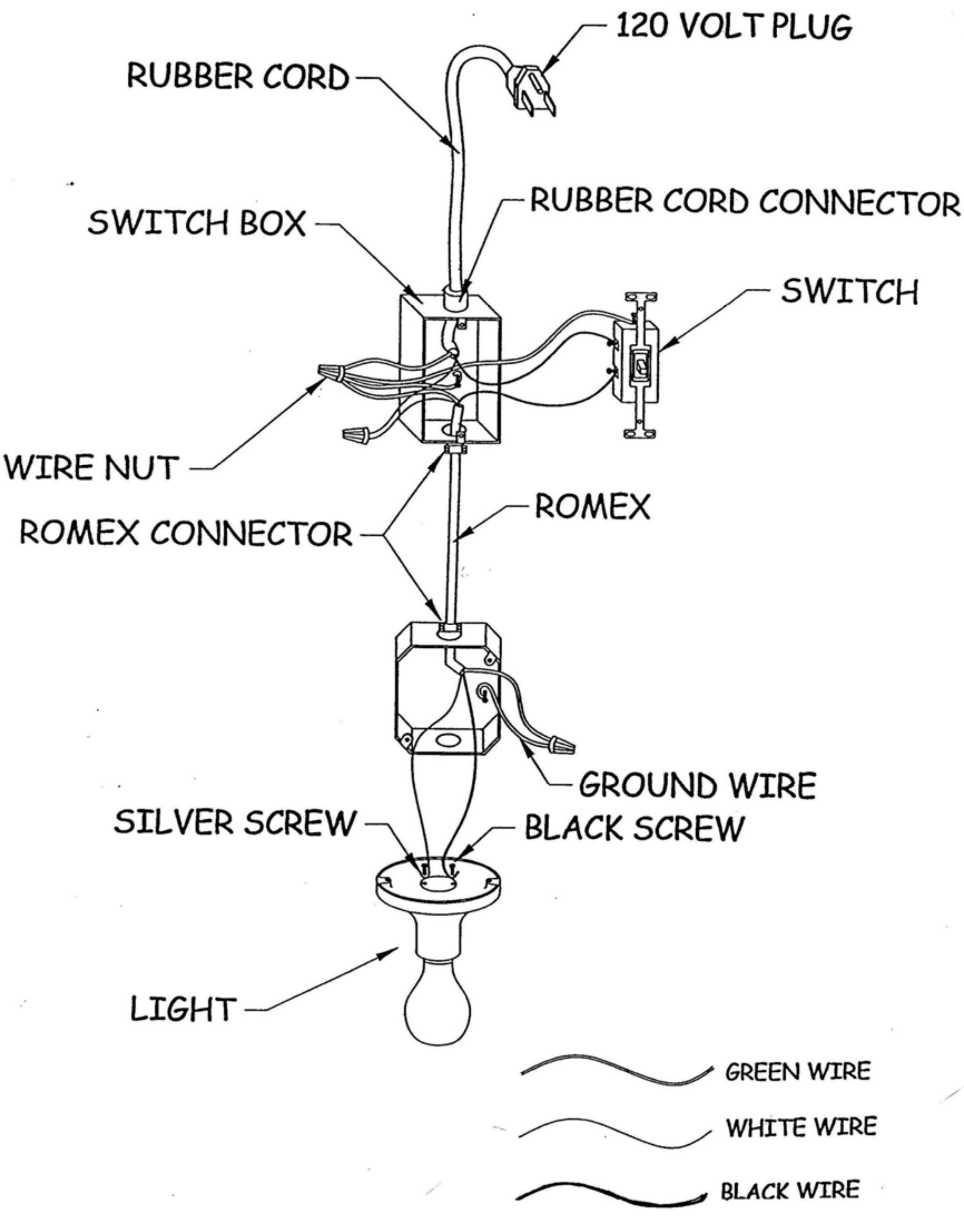
Water Power: Renewable power supply from a generating plant that uses water pressure from a reservoir to operate electric generating equipment.

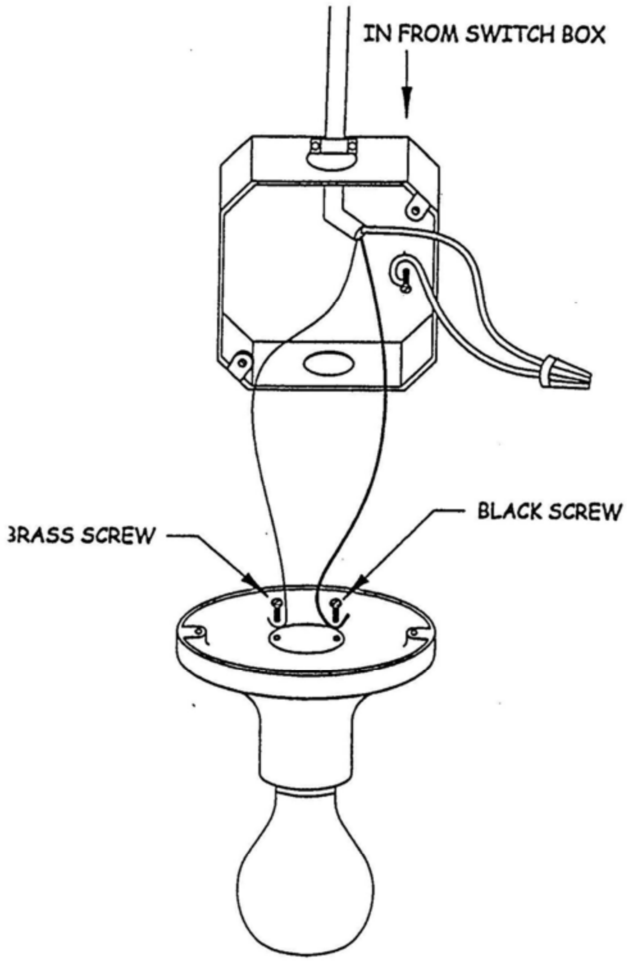
Watt: A unit of measure for electric power. One watt of power equals one volt of pressure times one ampere of current. Abbreviated "W".

Watt Hours: The number of watts of electricity used by a light, motor, heating or other electrical device in an hour. Abbreviated "wh", 1000 wh= I kilowatt hour (kWh).

Weather Head: The weather head is the connection between the service drop from the utility company and the service entrance conductors.

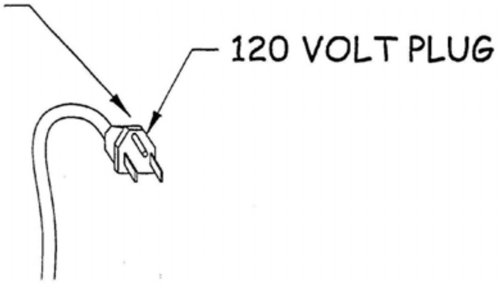
APPENDIX

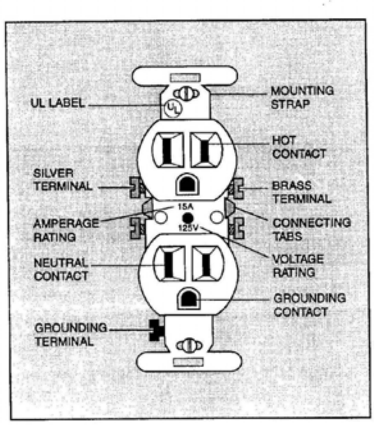

120 VOLT PLUG
RUBBER CORD
RUBBER CORD CONNECTOR
SWITCH BOX
SWITCH
WIRE NUT
ROMEX
ROMEX CONNECTOR
GROUND WIRE
SILVER SCREW
BLACK SCREW
LIGHT
GREEN WIRE
WHITE WIRE
BLACK WIRE



BLACK WIRE TO BLACK SCREW
WHITE WIRE TO BRASS SCREW
GREEN WIRE TO GROUND WIRE
ATTATCHED TO BOX

BLACK WIRE TO BRASS SCREW
WHITE WIRE TO SILVER SCREW
GREEN WIRE TO GREEN SCREW





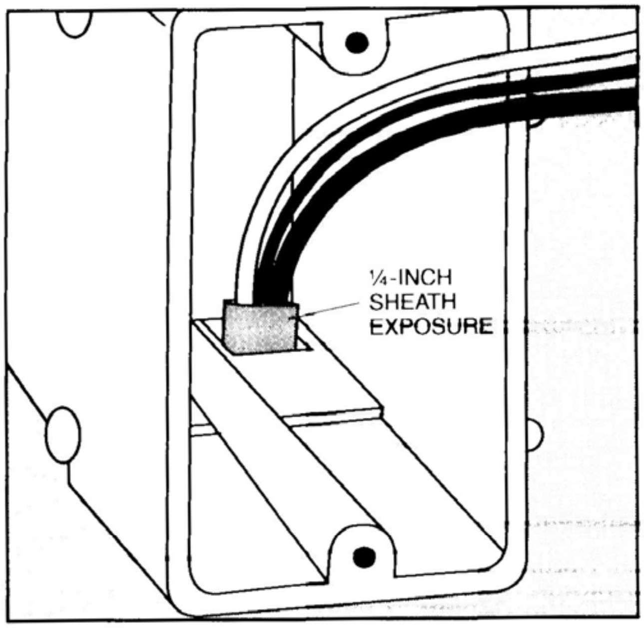


Figure 6-E-1. Cable clamps and cable connectors are not required to secure cable in nonmetallic boxes. The cable protective sheathing should extend up to 1/4-inch inside the box.

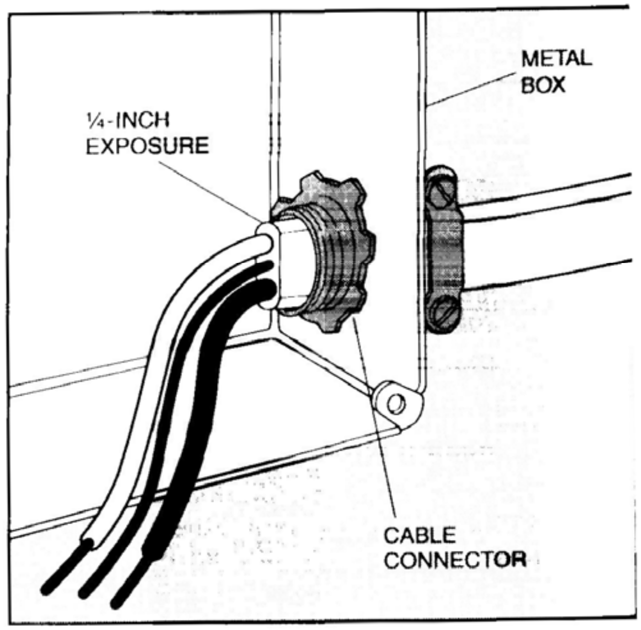
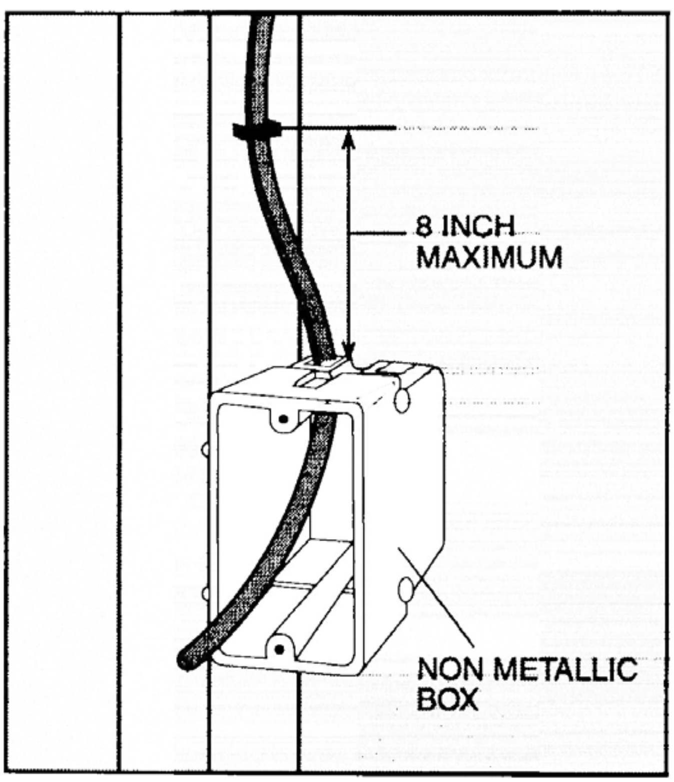


Figure 6-E-2. Metallic boxes require the use of cable clamps or cable connectors for securing cable. The protective sheathing on the cable must extend approximately 1/4-inch beyond the cable connector.



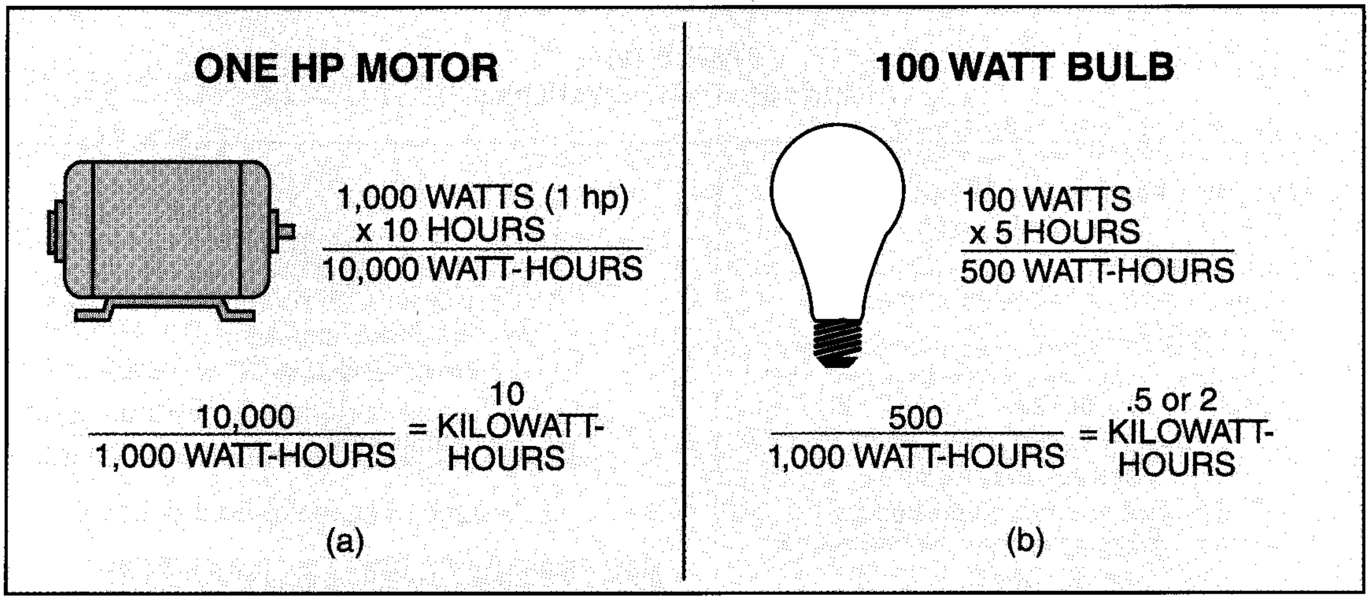


Figure 1-B-25. How to figure the amount of electric energy used by (a) a one-horsepower motor, and (b) a 100 watt light bulb.

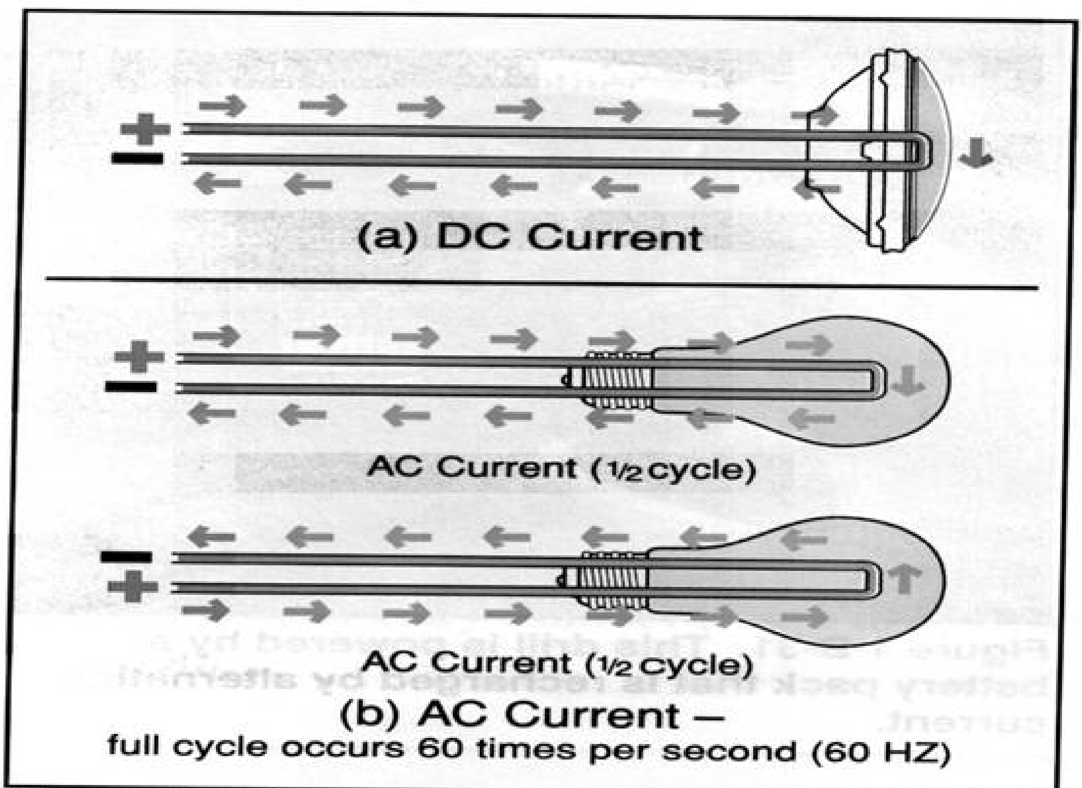
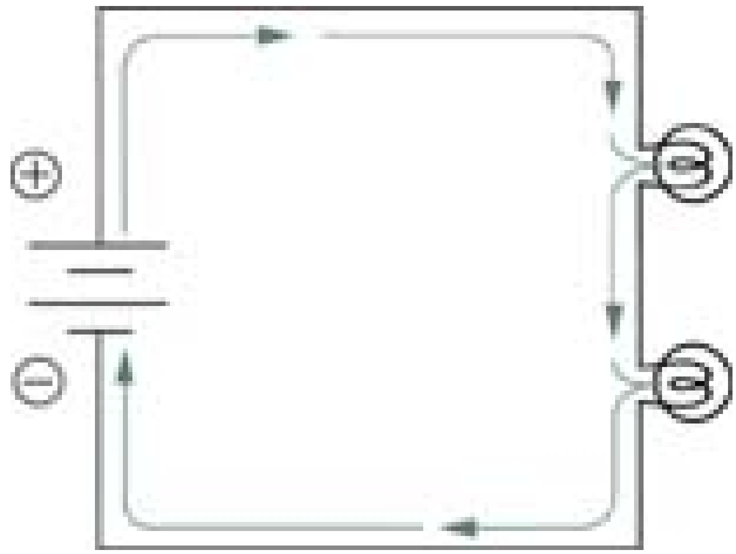
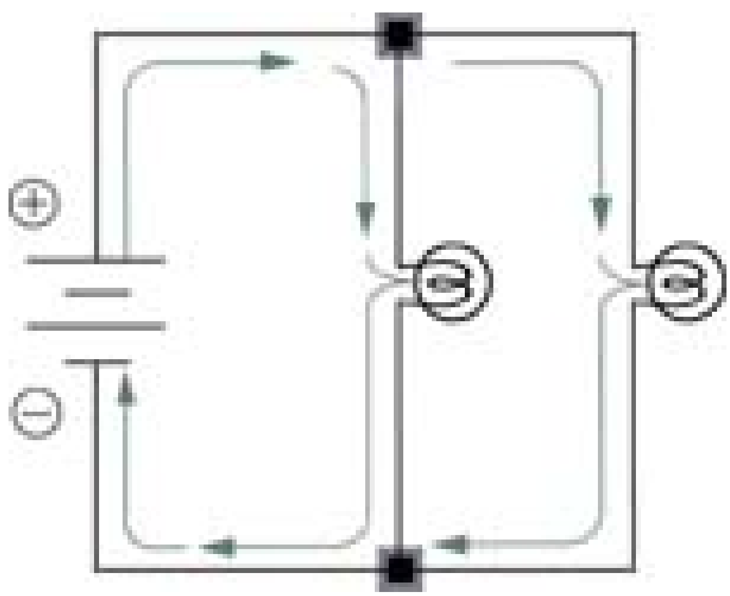


Figure 1-B-29. (a) DC current always flows in one direction, unchanging, as through this automotive headlight bulb. (b) AC current flows in one direction for one-half cycle, then reverses direction and flows in the other direction for one-half cycle, completing a cycle. This action occurs 60 times per second (60HZ).

Series Circuit



Parallel Circuit



Extension Cord Facts

What does AWG mean?

AWG means American Wire Gauge. It designates the size of the copper wire. The standard sizes for extension cords are 16 AWG, 14 AWG, 12 AWG and 10 AWG. The smaller the AWG number, the larger the size of the copper wire and wattage rating.

What do the AMP and Watt ratings mean?

Never plug more than the specific number of watts into a cord. For example, could you plug a 150 Watt lamp, a 60 Watt lamp and a 10 AMP appliance into an extension cord rated 13 AMPS/1625 Watts?

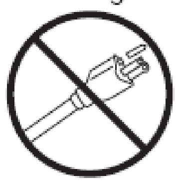
Use the AMP to Watt Conversion Table to determine the total number of Watts to be used (150 Watts + 60 Watts + 1250 Watts = 1460 Watts). Therefore it is safe to use the 13 AMP/1625 Watt extension cord.

Always look for the Underwriters Laboratory label which is permanently attached or molded into the cord. Read the label for instructions and electrical ratings.

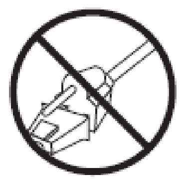
AMPS To WATTS (@ 125V) Conversion Table		
0	=	0
1	=	125
2	=	250
3	=	375
4	=	500
5	=	625
6	=	750
7	=	875
8	=	1000
9	=	1125
10	=	1250
11	=	1375
12	=	1500
13	=	1625
14	=	1750
15	=	1875

How to use an extension cord properly.

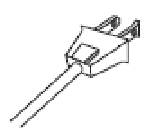
- Be sure the cord you have selected meets the intended use. Never use a cord outdoors that is not marked for outdoors.
- Inspect cord thoroughly before each use. Do not use if damaged.



- Do not remove, bend or modify any metal prongs or pins of plug.
- Look for the number of watts on appliances to be plugged into cord.
- Refer to UL Label on cord for specific wattage.
- Do not connect a three-prong plug into a two-hole cord.



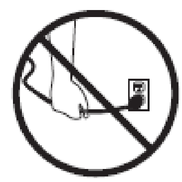
- Do not plug more than the specified number of watts into a cord.
- Make sure appliance is off before connecting cord to outlet.



- A polarized plug has one blade wider than the other.
- Fully insert plug into outlet.
- Do not use excessive force to make connections.
- Do not run cords through doorways, holes in ceilings, walls or floors.
- Do not use an extension cord when wet.

- Keep extension cords away from water.
- Keep children and pets away from extension cords.

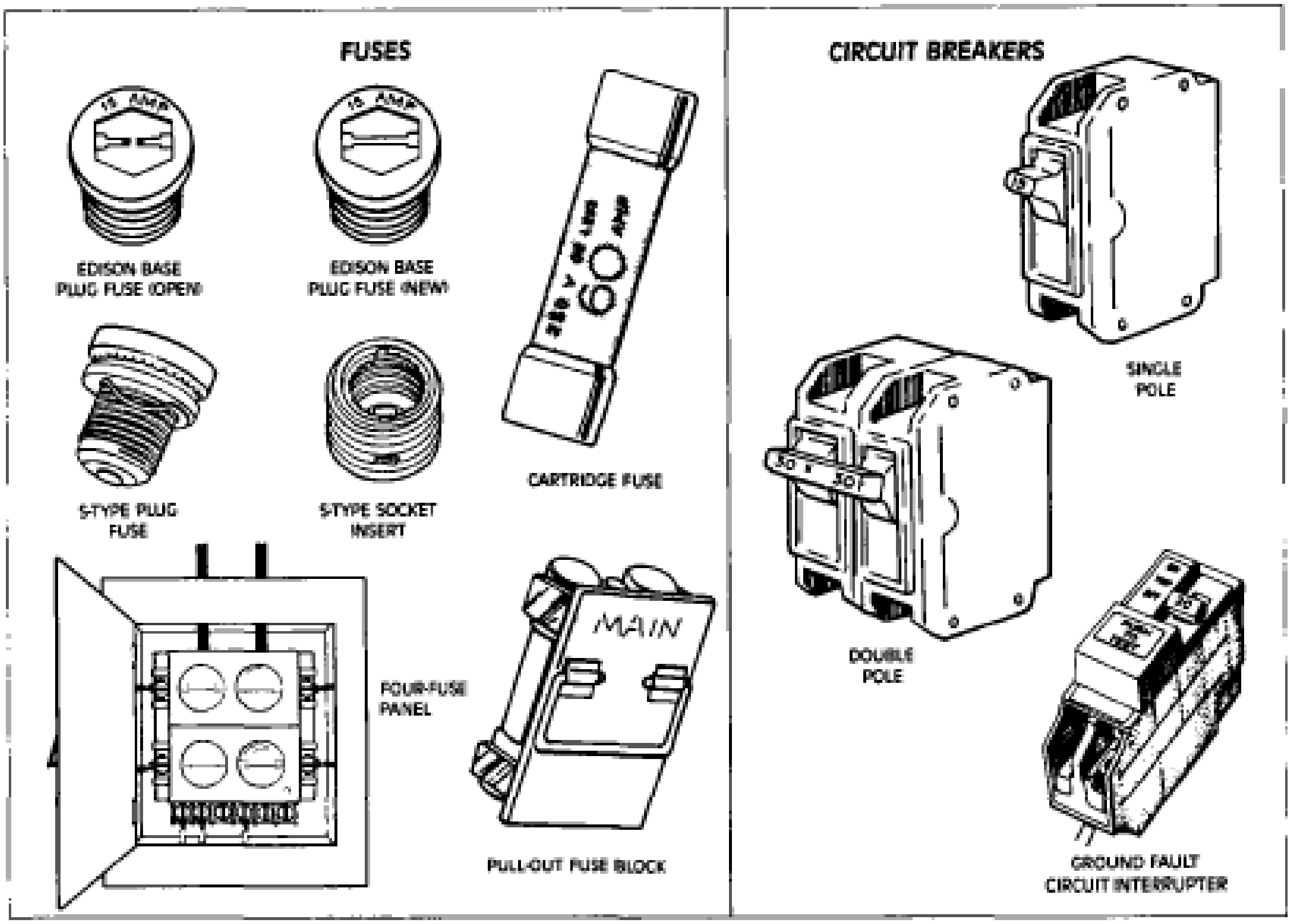
- Avoid overheating. Uncoil cord and do not cover it with any other material.
- Do not plug one extension cord into another.
- Do not drive, drag or place objects over extension cord.
- Always grasp plug when removing it from cord or outlet.
- Do not unplug by pulling on cord.



- Always store extension cords indoors.

- Do not walk on cord.
- Always unplug cord when not in use.
- Always look for the Underwriters Laboratory (UL) label which is permanently attached or molded into the cord. Read the label for instructions and electrical ratings.

FUSES/CIRCUIT BREAKERS
Warning Overrated panel



Fuses and circuit breakers are safety devices located on your electrical panel to prevent over loading and fires They stop the electrical current if it exceeds the safe level for some portion of the home electrical system Overloading means that the appliances and lighting in the home regularly demand more electrical current than the home electrical system can safely deliver

If the demand for electrical current exceeds the safe level a fuse opens once and must be replaced to reconnect the circuit. A circuit breaker trips its switch to open the circuit and the circuit is reconnected by closing the switch manually

There are at least two different types of circuit breakers One has a control handle that swings all the way to OFF when it is tripped The other has an intermediate position close to ON (sometimes it is difficult to see that it has tripped)

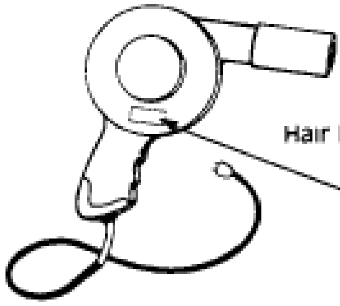
Both types of circuit breakers must be reset with the hand control after the problem has been eliminated The first type should simply be moved back to ON the second moved first to OFF and then to ON

APPLIANCE POWER BUDGET

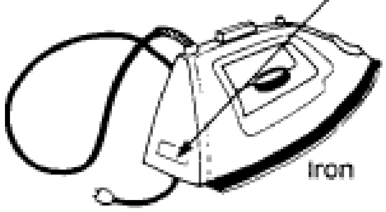
15 ampere branch circuit can carry 1500 watts*
20 ampere branch circuit can carry 2000 watts

Find nameplate with power (watts) rating

Add up total watts for appliances that you may use at the same time on the same branch circuit



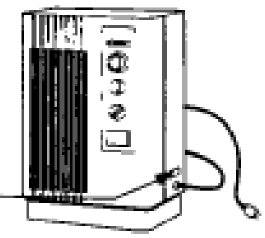
Hair Dryer



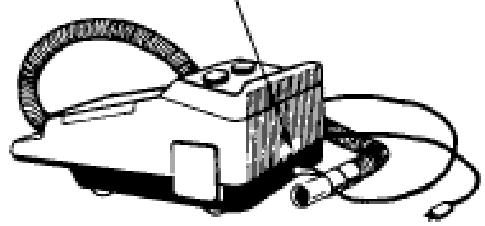
Iron

1400 watts
+ 1000 watts
2400 watts
too much for 15 A or 20 A

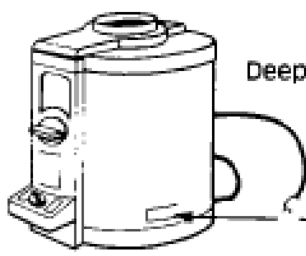
Portable Heater



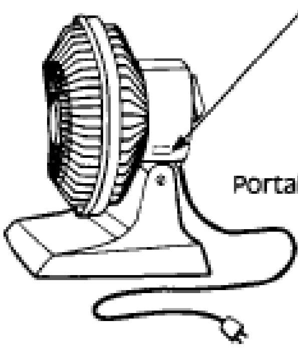
1200 watts
+ 600 watts
1800 watts
O K for 20 A
too much for 15 A



Vacuum Cleaner



Deep Fat Fryer



Portable Fan

1300 watts
+ 150 watts
1450 watts
O K for 20 A or 15 A

* Most home lighting and receptacle outlet branch circuits may carry as much as 1500 watts (15 ampere branch) some kitchen circuits as much as 2000 watts (20 ampere)

ENERGY MATH:
A hair dryer or a porch light—which costs more to run?

When an appliance has a high power rating, it doesn't necessarily mean the appliance uses more energy. It depends on how much the appliance is used.

Let's compare a hair dryer rated at 1,500 watts, with a 60-watt light bulb.

The hair dryer is used every day for 10 minutes. The light bulb is lit 8 hours per night as a security measure.

Let's assume the utility rate is $.17 per kilowatt hour.

Kilowatt hours = (watts x hours) / 1,000

Hair dryer

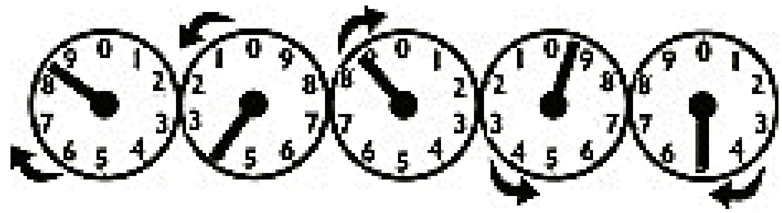
1. Hair dryer uses 1,500 watts, 10 minutes per day for 30 days (1 month)
2. Hours = 10 minutes per day x 30 days = 300 minutes = 5 hours
3. Kilowatt hours = 1,500 watts x 5 hours = 7,500 watt-hours = 7.5 kWh
4. Dollars = 7.5kWh x $.17 per kWh = $1.28 per month to operate the hair dryer

Porch light

1. Porch light uses 60 watts, 8 hours per day for 30 days (1 month)
2. Hours = 8 hours per day x 30 days = 240 hours
3. Kilowatt hours = 60 watts X 240 hours = 14,400 watt-hours = 14.4 kWh
4. Dollars = 14.4 kWh x $.17 per kWh = $2.45 to operate the porch light

The hair dryer draws 25 times more power than the light bulb (1,500 watts vs. 60 watts) but uses half as much energy each month (7.5 kWh vs. 14.4 kWh). If you have a renewable energy home, you can power the light bulb but probably not the hair dryer, even though the hair dryer uses far less energy per month.

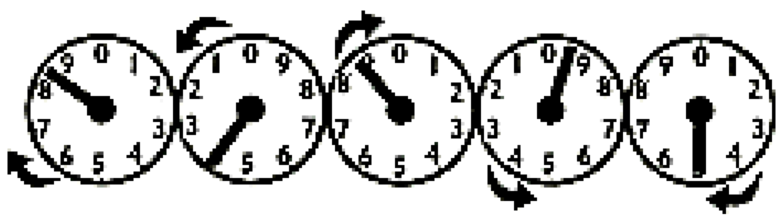
How to Read a Meter



When reading an electric meter, keep these hints in mind: **Reading: 83770**

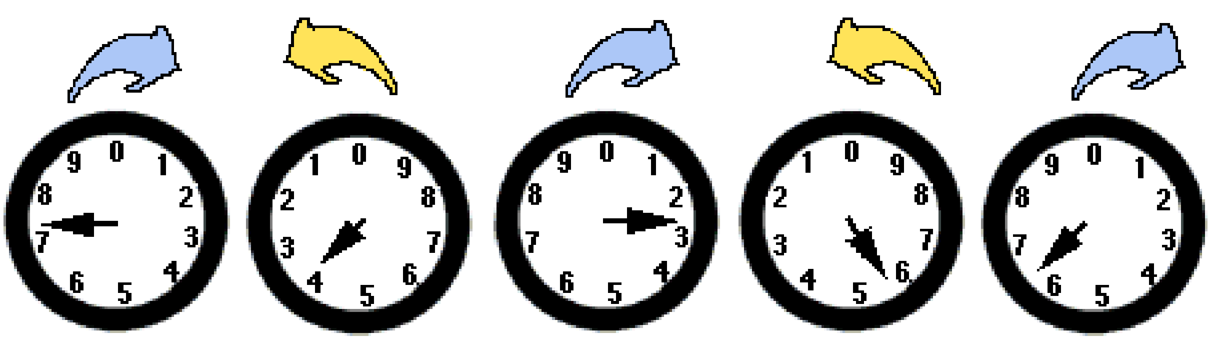
- Stand directly in front of the meter so that you can clearly see the location of each pointer.
- Read the numbers from RIGHT to LEFT, and write them down in the same order.
- If the pointer is between two numbers, read the number the pointer has just passed, always the lowest number.
- If the pointer is between 9 and 0, always read 9.
- If the pointer appears to be exactly on a number, read the next lowest number unless the pointer to its right has passed zero. Since the first dial has no dial to its right, the number must be read independently.
- If your meter has digital numbers, use those as your reading.

What is the reading of the example electric meter shown below?

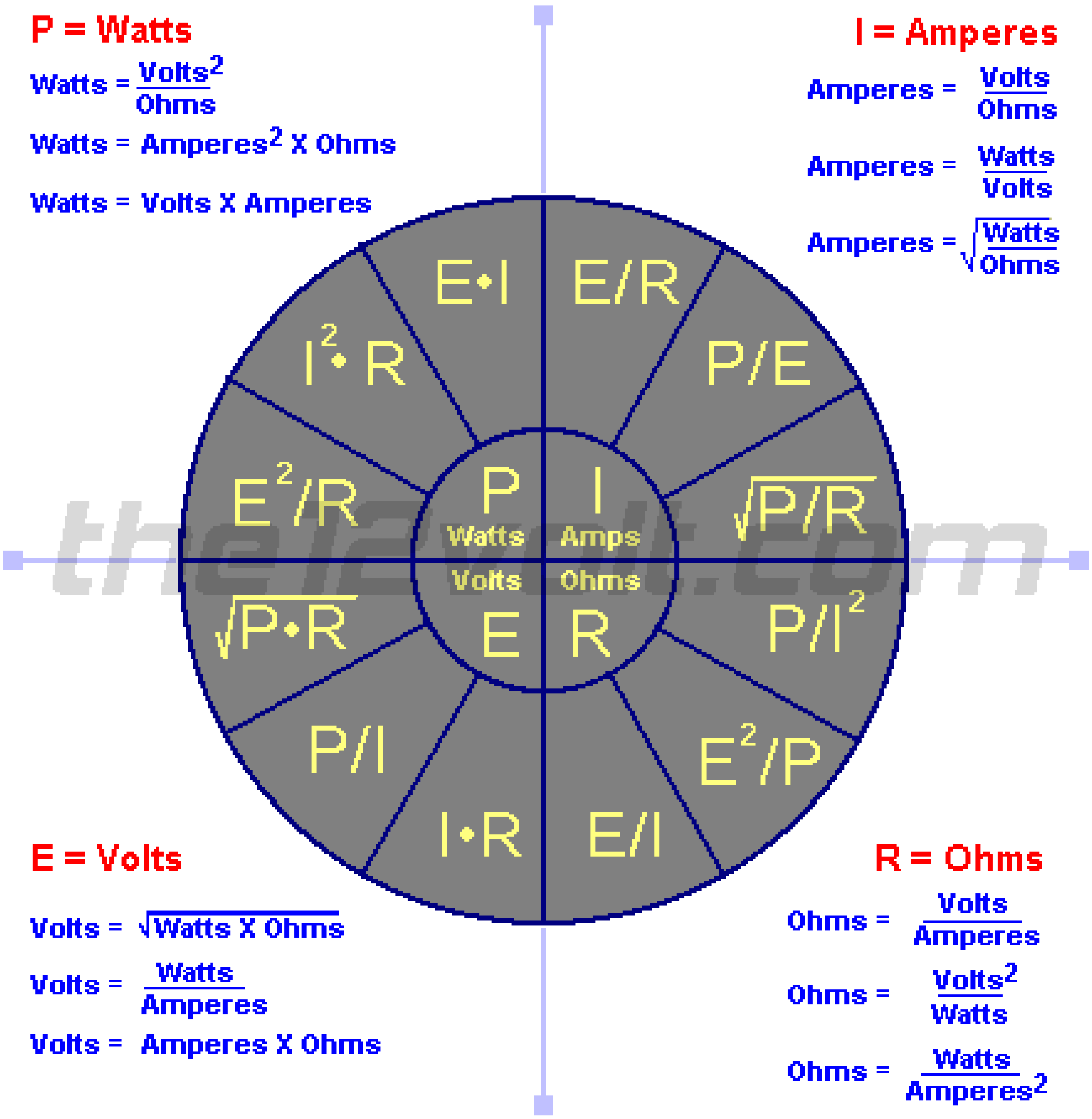


A. The pointer on the far right is directly on number 5. Read as 5.
B. The second pointer from the right has just passed 9, and is between 9 and 0. Read as 9.
C. The next dial has passed 8, and is between 8 and 9. Again, read the smaller number which the pointer has just passed, which is 8.
D. The pointer on the next dial looks like it is right on the 4. But, the dial to its right has not passed zero. So, you would read this dial as 3.
E. The pointer on the far left dial has passed 8, and is between 8 and 9. Read the smaller number which the pointer just passed, which is 8.

Current reading: **83895** Last week's reading: **-83770** Electricity use this week **= 125 kwh at 17 cents a kWh – the bill will be: $21.25**



What is the reading for this meter?


P = Watts
Watts = Volts² / Ohms
Watts = Amperes² X Ohms
Watts = Volts X Amperes
I = Amperes
Amperes = Volts / Ohms
Amperes = Watts / Volts
Amperes = √(Watts / Ohms)
E = Volts
Volts = √(Watts X Ohms)
Volts = Watts / Amperes
Volts = Amperes X Ohms
R = Ohms
Ohms = Volts / Amperes
Ohms = Volts² / Watts
Ohms = Watts / Amperes²
P
Watts
I
Amps
E
Volts
R
Ohms
E•I
I²•R
E²/R
E/R
P/E
√P/R
√P•R
P/I
I•R
E/I
E²/P
P/I²
the12volt.com

Electrical Symbols

Lighting Outlets

- Ceiling Outlet
- Fluorescent Fixture
- Continuous Row Fluorescent Fixture

Receptacle Outlets

- Single Receptacle Outlet
- Duplex Receptacle Outlet
- WP Weatherproof Receptacle Outlet
- R Range Receptacle Outlet
- Duplex Receptacle Outlet (split wired)
- S Switched Convenience Outlet
- Special Purpose Outlet
- D Dryer Outlet
- J Ceiling Outlet (junction box)
- J Wall Outlet (junction box)
- GFCI Ground Fault Circuit Interrupter
- P GFCI Protected Receptacle
- R Recessed Fixture Outlet

Switch Outlets

S	Single Pole Switch
S_2	Double Pole Switch
S_3	Three-Way Switch
S_4	Four-Way Switch
S_F	Fan Switch
S_P	Switch and Pilot Light
M	Motor Switch
T	Time Switch

Service Entrance Panels

- Service Entrance Panel (SEP)
- Surface Mounted SEP or Subpanel
- Subpanel (MLO) Main Lugs Only

Overcurrent Devices

- Single Pole Breaker
- Double Pole Breaker (handle-tie)
- Fuse

Disconnects

- Non-Fusable
- Fusable

Electrical - Common Electrical Codes

Before you do any kind of electrical work, you should know what codes pertain to your project because they determine how electrical work should be done. Electricians follow the **National Electric Code** (NEC) to figure circuit wiring and capacity necessary for each situation. It's a fairly complex guide, so you may want to consult your local inspector for more help in clarifying codes.

As you plan out circuits, keep in mind that it's generally better and safer to have more available circuits and extra capacity, than too few.

Figure in any future updates and a maximum load demand each circuit may have when making a diagram.

General Guidelines Here are a few typical guidelines that do-it-yourselfers should know about when doing electrical work. These are NOT legal interpretations of the National Electrical Code, so check with your local authority before starting work:

Kitchens

- All the **kitchen**, breakfast room, pantry, and dining room outlets must be supplied by at least two 20-amp small appliance circuits.
- Outlets above the kitchen counter normally are fed by **both** circuits -- they all cannot be wired to just one circuit. The circuits should not supply any lights or other outlets in the house.

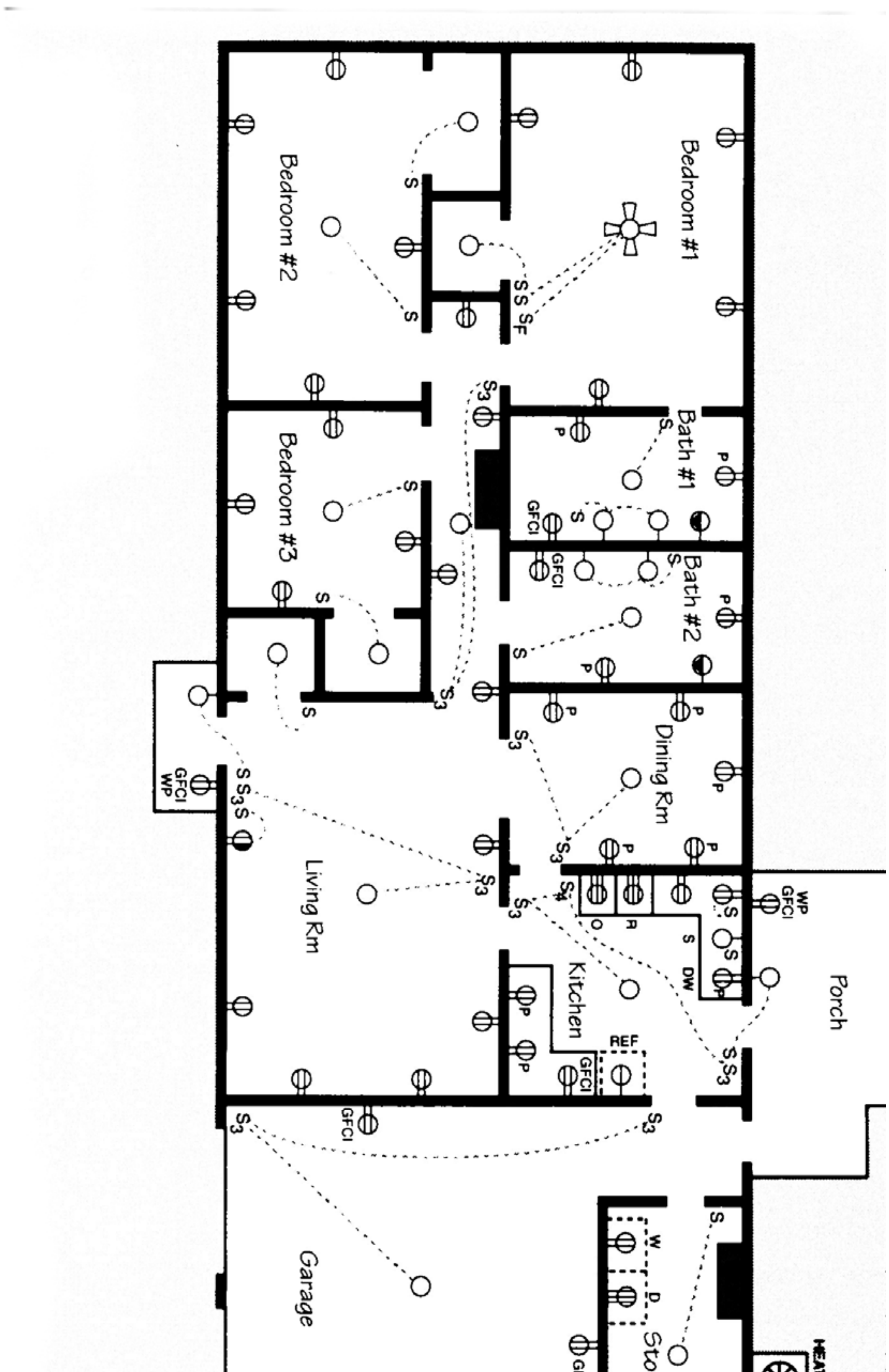
Appliances

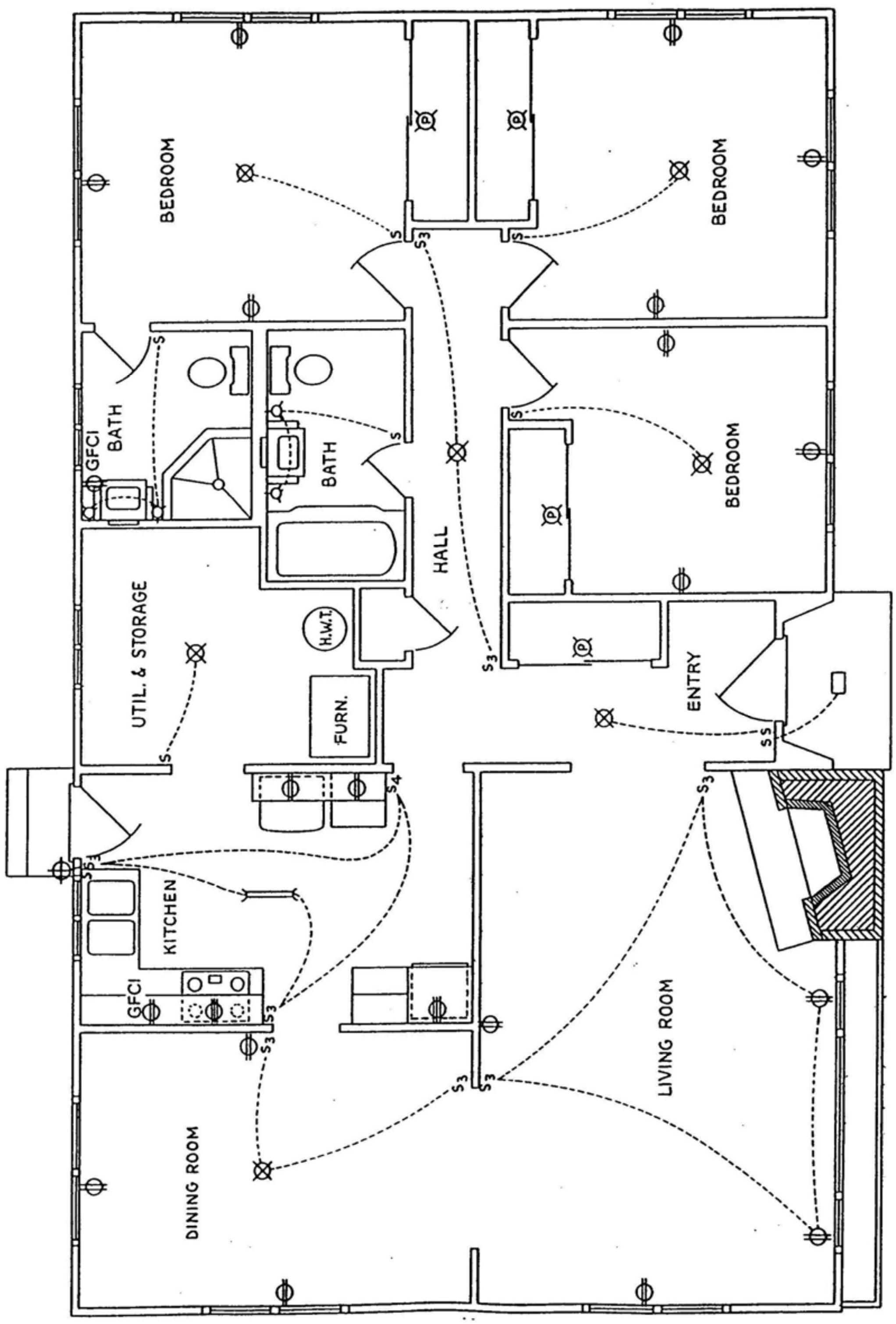
- Separate circuits are needed for built-in **appliances** (i.e. oven, range, disposer, dishwasher, central air conditioner, and furnace).
- One 20-amp circuit is needed for the **laundry** outlet within 6' of the machines. An electric dryer requires an additional 240-volt circuit.

Outlets

- One lighting/convenience **outlet** circuit for every 575 square feet of floor space in a house.
- Any bathroom or garage outlet within 6' of a sink must be GFCI protected. A new code requires **all** kitchen outlets for countertop use to be GFCI protected.
- At least one GFCI outlet is required in an unfinished basement and for most outdoor outlets (exceptions include inaccessible outlets like at a garage ceiling or behind a refrigerator.
- Any point along the bottom of a wall (which is 2' or wider) must be within **6'** of an outlet. The 6' distance cannot be measured across a doorway or fireplace. And the outlet must be within 5 1/2' of the floor. This code cuts down on extension cord use, especially across doorways, fireplaces and similar openings. Switches

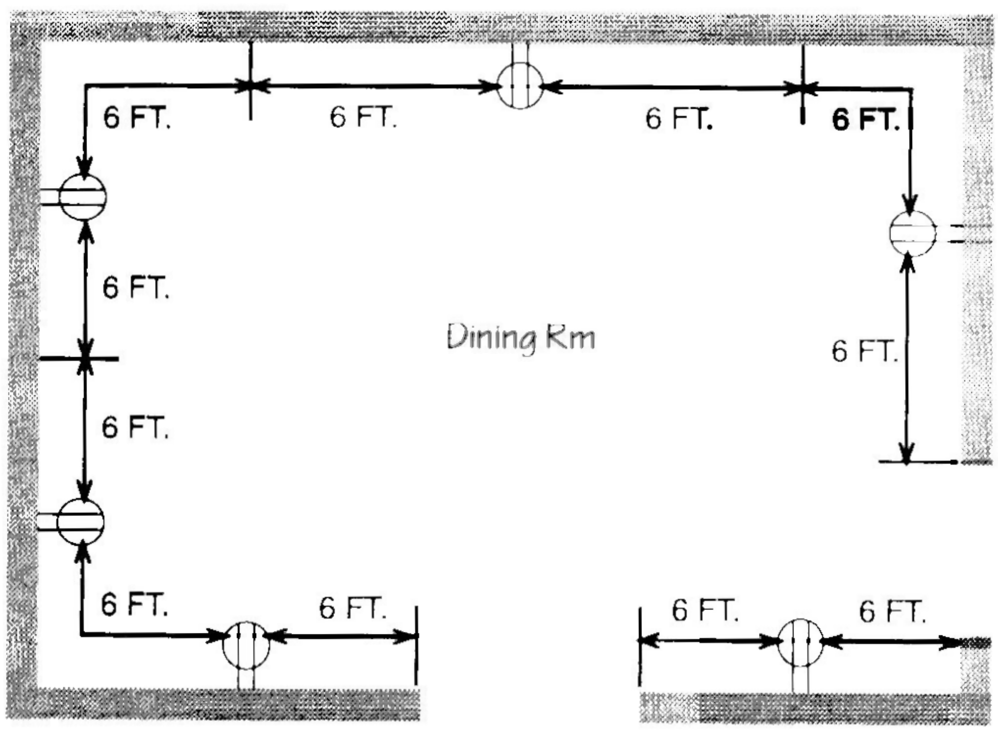
- A **light switch** must control lighting in every habitable room, hallway, stairway, or garage. The switch can control either a light fixture or a receptacle into which a lamp is plugged.
- In kitchens and bathrooms, the light switch must control a permanently installed light fixture.


Bedroom #1
Bedroom #2
Bedroom #3
Bath #1
Bath #2
Dining Rm
Living Rm
Kitchen
Porch
Garage
Storage
HEAT PUMP
REF


BEDROOM
BEDROOM
BEDROOM
GFCI
BATH
BATH
HALL
UTIL. & STORAGE
H.W.T.
FURN.
ENTRY
KITCHEN
GFCI
LIVING ROOM
DINING ROOM

Wall Outlets

The National Electrical Code (NEC) requires wall receptacles outlets to be located so that no point along an unbroken wall measures greater than 6 feet between outlets. This includes any wall space of two feet or more in width. Wall space is defined as a wall unbroken by a doorway, fireplaces, or similar openings. The customary accepted height for most wall receptacle installations is between 12 and 16 inches above floor level.



Type of Box	Size in Inches (Height × Width × Depth)	Maximum Number of Wires Allowed in a Box 14-gauge	12-gauge	10-gauge
switch/ receptacle	3×2×1½	3	3	3
	3×2×2	5	4	4
	3×2×2¼	5	4	4
	3×2×2½	6	5	5
	3×2×2¾	7	6	5
	3×2×3½	9	8	7
utility	4×2⅛×1½	5	4	4
	4×2⅛×1⅞	6	5	5
	4×2⅛×2⅛	7	6	5
fixture/ junction	4×1¼ round or octagonal	6	5	5
	4×1½ round or octagonal	7	6	6
	4×2⅛ round or octagonal	10	9	8
	4×1¼ square	9	8	7
	4×1½ square	10	9	8
	4×2⅛ square	15	13	12
	4¹¹⁄₁₆×1½ square	14	13	11
	4¹¹⁄₁₆×2⅛ square	21	18	16

Electrical Math Problems

Minimum Box Volume For Metal

- □ All conductors entering box (hot and neutral)
- □ Ground wires (count only 1 for all present)
- □ Cable clamps (count only 1 for all present)
- □ Receptacle that fits into box counts as 2
- □ Total wires
- □ Allow 2 cubic inches per wire for 14 gauge wire
- □ Allow 2.25 cubic inches per wire for 12 gauge wire

Example: 8 wires X 2 cubic inches = 16 cubic inches minimum

Minimum Box Volume For Standard Plastic Box

- □ All conductors entering box (hot and neutral)
- □ Ground wires (count only 1 for all present)
- □ Cable clamps (usually 0)
- □ Switch or receptacle that fits into box counts as 2
- □ Total wires
- □ Allow 2 cubic inches per wire for 14 gauge wire

Example: 5 wires X 2.25 cubic inches = 11.25 cubic inches

Using above information is the switch box and outlet box in your kit of adequate size?

Switch box _______cubic inches
Outlet (1 amp) box ______cubic inches

Math Problems

1. A 500 watt block heater in your tractor is connected to 120 volts. How many amperes of current does the block heater take ______________amps.

2. An electric heater in your dairy barn office is rated at 7.5 amperes and is connected to a 240 volt circuit. Find the power in watts for the heater. ________watts

3. What voltage is necessary to cause a current of 1.74 amperes to exist in a 200-watt lamp? _____________voltage

4. Your soldering iron uses 6 amperes of current when plugged into a 120 volt circuit. Your circuit can safely handle 1800 watts. How many soldering irons can you use on this one circuit at one time. ______Soldering irons

5. **The electric company charges 15 cents per kilowatt-hour. George used 2800 kilowatt-hours in April, 2000 kilowatt-hours in May, and 1500 kilowatt-hours in June. What was his average cost of electricity for the 3 months?** ____________________________

6. What will it cost to run the block heater in example #1 for 8 hours each night for a 30 day month if electricity is **15 cents per kilowatt hours?** ________________

7. What will it cost to run the electric heater for 3 hours each day for 7 days at **15 cents per kilowatt hours?** ______________________

a. **If a 10 ampere microwave oven is used for 12 hours per month while a 20 ampere electric clothes dryer is used for 6 hours monthly, which would used the most power if both are on 50% of each hour of operation. Show your calculations for each appliance:**

Microwave oven: ________ A x ________W = ____________ watts

________ W x ________ hrs. =_____________ watt hours

__________ WH / ___________ =______ KWH used in one month

Electric clothes dryer:_______ A x __________ V = ____________ watts

__________ W x ________ hrs. = _____________ watt hours

___________ WH / ___________ = _________ KWH used in one month

b. **If the electric energy rate is $.10 for each kwh, which appliance costs the most to operate? Show your calculations.**

Microwave oven:_________ KWH x _________ = $ _______ power cost in one month

Electric clothes dryer: ________ KWH x ________ = $ _______ power cost in one month

c. **If a 40 watt fluorescent tube is used 8 hrs. daily and a 100 watt incandescent bulb is used 8 hrs. daily, what would each cost to operate in a month at $.10 per KWH. Show your calculations.**

40 watt fluorescent tube _______ W x _______ hrs. = ____________ watt hours daily

________ WH x ________ days =__________ watt hours used per month

______________ WH = _______ KWH used per month _______ KWH x ________ = $ ______ cost of operation for one month

100 watt incandescent lamp:________ W X ________ hrs. = _________ watt hours used daily

_________ WH x __________ days = __________ watt hours used per month

__________ WH / ________ = _______ KWH used per month ________ KWH x _______ = $_______ cost of operation for one month

Electricity Calculations

Directions: Fill in the blanks in the tables below.

Table 1

Voltage	=	Current	x	Resistance
1.5 V	=	A	x	3 Ω
V	=	3 A	x	4 Ω
120 V	=	4 A	x	Ω
240 V	=	A	x	1 2 Ω

Table 2

Power	=	Voltage	x	Current
27 W	=	9 V	x	A
W	=	120 V	x	1.5 A
45 W	=	V	x	3 A
W	=	120 V	x	2 A

Table 3

Appliance	Power	=	Voltage	x	Current
TV	180 W	=	120 V	x	
Computer	40 W	=	120 V	x	
Printer	120 W	=	120 V	x	
Hair Dryer	1,000 W	=	120 V	x	

Table 4

POWER	x	TIME	=	ELECTRICAL ENERGY	x	PRICE	=	COST
5 k W	x	100 h	=		x	$0.08	=	
1000 W	x	1 h	=		x	$0.08	=	
25 kW	x	4 h	=		x	$0.08	=	

Directions: Answer the questions below in the space provided.

Calculate the annual cost to run an appliance for a year.

1. After school each day, James uses his computer to do his homework. If he has an average of two hours of homework per night for 180 days of school per year, how many kilowatt-hours are consumed and what is the annual cost of using his computer? A CPU and monitor use 270 Watts.

2. Choose a home appliance that you use and calculate your own energy consumption.

Appliance: _________________

Wattage: __________________

Hours used Per Day: ________

wattage x hours used per day x days used per year = kilowatt-hour (kWh) consumption
1000

Multiply this number by MPS's rate per kWh (17 cents/kWh) to calculate annual cost.

Example:

If John uses a window fan (200 watts) 4 hours a day for 120 days per year, how much does it cost him to run his fan per year?

200 W x 4 h/d x 120 d = 96 kWh 1000

96 kWh x 0.17 cents/kWh = $16.32 per year

3. **Lighting Dilemma** - How much energy/money can be saved by replacing 100 watt incandescent light bulbs with 27 Compact Fluorescent Lights?

A. Search your home and count the number of lights in each room.

B. Calculate the number of hours the lights are used in each room each day.

C. Enter the data below.

	Number of Lights	**Number of Hours**	**Lights X Hours = TOTAL**
Living Room			
Dining Room			
Kitchen			
Bedrooms			
Bathrooms			
Hallways			
Room			
Outside Lights			
TOTAL			

D. Each energy efficient CFL bulb saves 73 watts, how many watt-hours could you save if you replaced all bulbs with CFLs?

total hours of operation x 73 watts = _________ watt-hours you would save each day

Divide your answer by 1000 since there are 1,000 watt-hours in a kilowatt-hour (which is how your utility bills you)

watt-hours/1000 = __________ kilowatt-hours you would save

Take this answer and multiply it by 365 (the days in a year) to calculate the Kilowatt-hours saved in a year.

kilowatt hours X 365 = __________ kilowatt-hours saved in a year

To calculate the amount of money your family could save in a year, take the kilowatt-hours saved in a year times the cost per kilowatt-hour (13 cents per kWh).

kilowatt-hours saved x $0.17 = __________ amount saved per year!

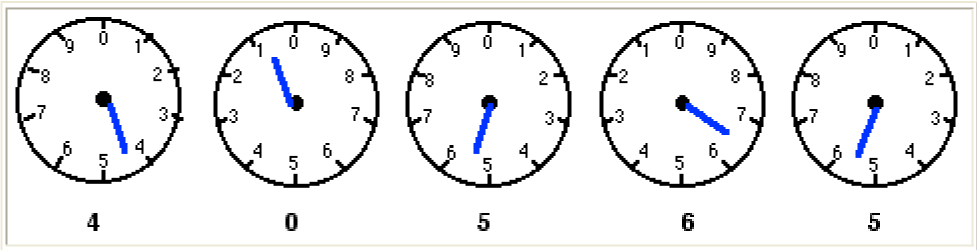
In addition to saving money, we use less electricity! Using less electricity means producing less greenhouse gases. If we assume that every kilowatt-hour saved removes 2 pounds of carbon dioxide from the air, how much greenhouse gases could be prevented?

kilowatt-hours saved in a year x 2 pounds = ___________ pounds of greenhouse gas prevented

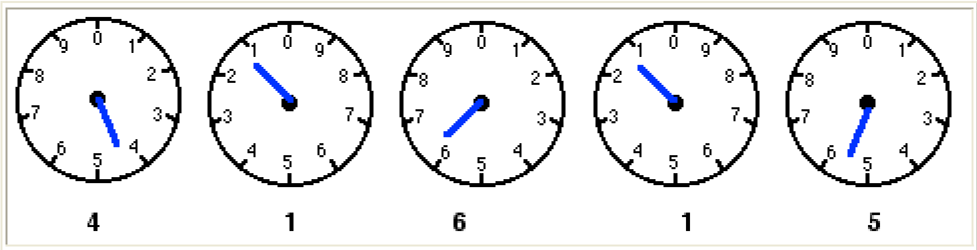
4. **Reading Electric Meters**

Example:

Monday morning the meter looked like this:



Friday morning the meter looked like this:

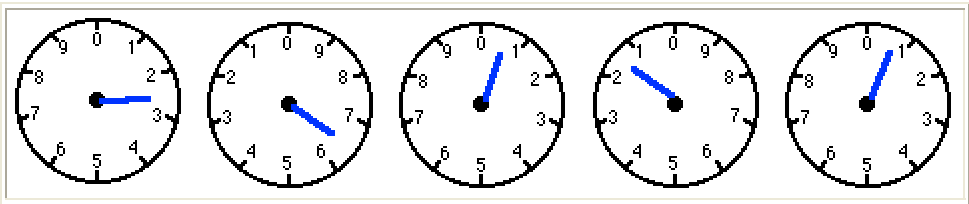


The meter reading Monday would be 40565 and on Friday it would be 41615

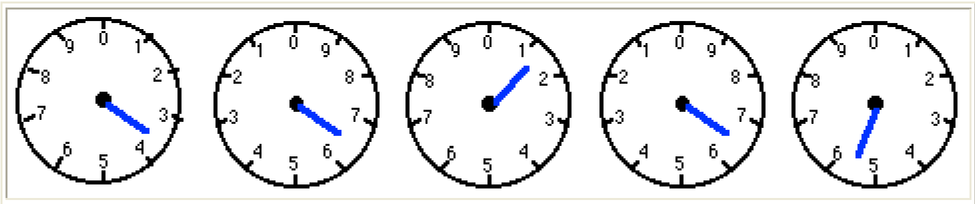
To figure out how much electricity was used, subtract Monday's reading from Friday's reading and multiply by the electricity costs. (Electricity costs $0.13 per kWh.) TOTAL COST = 1050 kWh x $.17 per kWh = $178.50

Problem:

On January 1, the meter looked like this:



On January 31, the meter looked like this:



How many kilowatt-hours of electricity were used during January?

If the cost of electricity in Aroostook County is $0.17 per kWh, how much did electricity cost for January?

What is the average cost of electricity per day during January?

Comments:

Answers to Math Problems on Page 65.

1. 500 watts/120 volts – 4.2 amps

2. 7.5 amps X 240 volts = 1800 watts

3. 200 watts / 1.74 amps = 114.9 volts

4. 6 amps X 120 Volts = 720 watts   1800 watts/720 watts = 2.5 irons

5. April = 2,800 kWh; May = 2,000 kWh; June = 1,500kWh
   Total is 6,300 kWh X .15 = $945.00; Average for 3 months is $315.00

6. 500 watts X 9 hours = 4500 watthours/1000 – 4.5 kWh X 30 days = 135 kWhs per month X .15 cost per kWh = $20.25

7. 1800 watts X 21 hours (3 hours for 7 days) = 37,800 watts/1000 = 37.8 kWh X .15 = $5.67